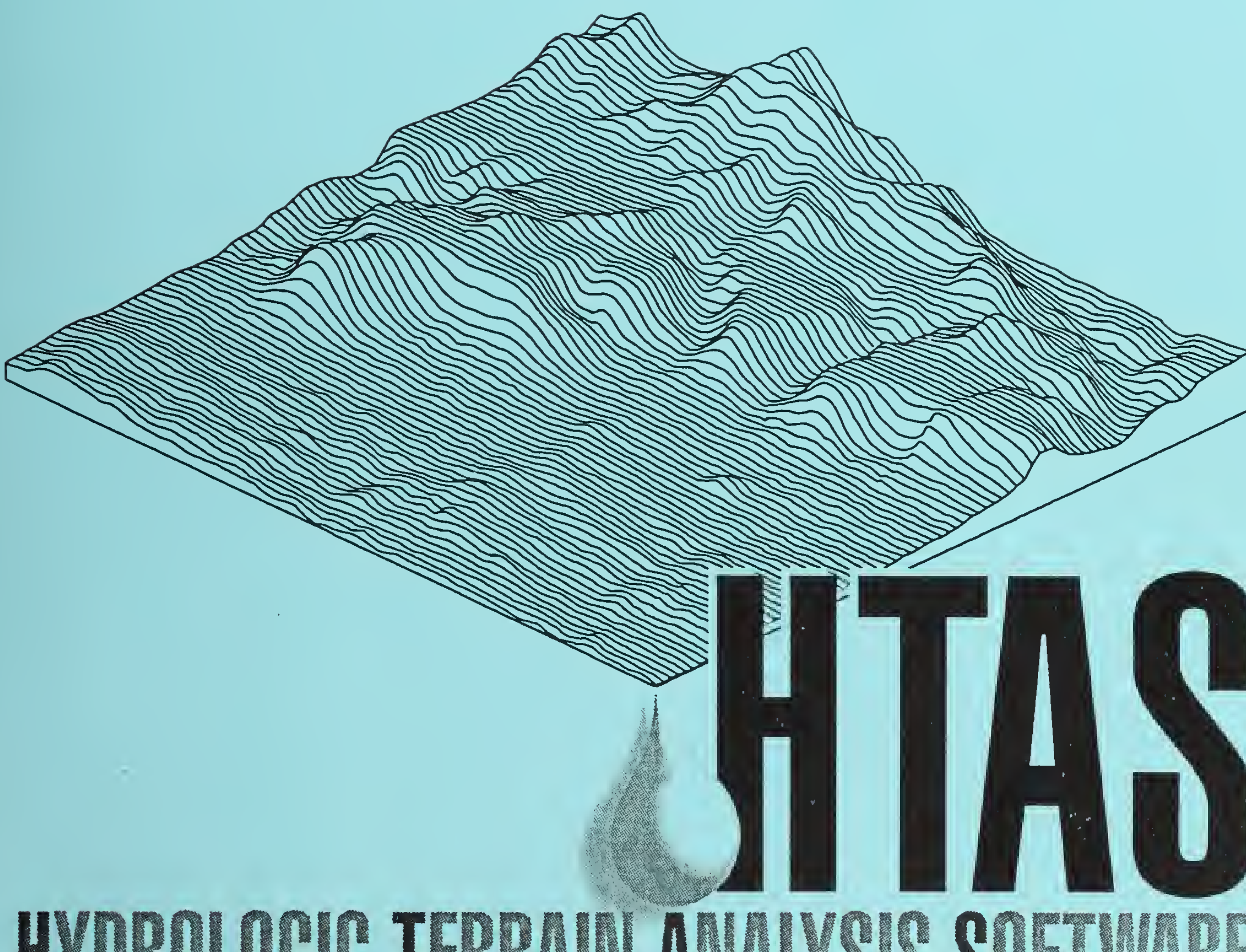

HTAS

HYDROLOGIC TERRAIN ANALYSIS SOFTWARE

USER'S MANUAL

This version: May 20, 1993

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USER'S MANUAL

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Hydrologic Terrain Analysis Software, May 20, 1993

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Contents

Hydrologic Terrain Analysis Software

Acknowledgements

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Introduction
Getting Started/Operation

In the late 1980s S. Jenson from the Eros Data Center developed a series of FORTRAN programs to extract surface hydrologic information from digital terrain data (Jenson and Domingue, 1988). The Hydrologic Terrain Analysis Software (HTAS) adds to the existing GIS terrain analysis capabilities a series of tools used to aid sound design of resource and environmental planning and management projects which utilize information about surface hydrologic processes. Among its many capabilities, HTAS permits discovery of surface depressions, flow accumulation, flow directions, and drainage pattern and watershed delineation, with a choice of manual or automatic selection of potential watershed outlets. Potential applications include a variety of modeling goals, such as, runoff and sediment yield modeling, stream-flow modeling, dam and reservoir design, erosion control structure design (such as spreaders), riparian area studies including input of sediment and pollutants into streams, and aquifer recharge area discovery. Some of these applications have been or are being developed, and others are yet to be identified.

This manual provides an introduction to the concept and the capabilities of the HTAS, as well as step by step instructions on its use. Although at this time the BLM's Map Overlay and Statistical System (MOSS) and Map Analysis Processing System (MAPS) software do not include the HTAS capabilities as commands, and the GIS interface remains cumbersome, we believe that the benefits of using the software offset the difficulties.

Program Installation and Execution

The HTAS consists of 14 FORTRAN programs which run under the Primos, UNIX, or VMS operating systems. Each program compiles and runs as an independent unit, consequently no subroutine libraries are required. The attached diskette contains the executable version of the programs compiled under Primos. Create a directory to store these programs and copy them off of the diskette. To execute the programs use the Primos RESUME (R) command using the format:

```
R (path) (filename)
```

If starting at the directory where you stored the programs e.g., `IS>HYDRO`, type:

```
R CONCAVE
```

If starting at any other location type the entire pathname:

```
R IS>HYDRO>CONCAVE
```

Prompting

The programs prompt for various parameters, including the size of the map being processed in lines (rows) and samples (columns), file names and system name before processing begins. Enter the file names and system name (PRIME) enclosed in single quotes, e.g., 'PRIME'.

```
R DELTA

ENTER NL,NS,DIR FILE,COUNT FILE,DELTA
FILE,SYSTEM(UNIX,VMS,PRIME)

1334,1279,'DIR.MAP','LEV.MAP','DELTA.MAP','PRIME'
```

File characteristics and file transfer

The programs operate on binary I*2 and I*4 disc files. They require direct access, fixed length record file type to access information at any place in the file at will. The program CONVERT permits transfer of IDIMS files into direct access, fixed length format. The MOSS/MAPS interface part contains additional information on this process.

All the raster data sets exist in the I*2 format (cell values are represented as an integer value stored in a two byte or 16 bit format) except for the COUNT and DELTA data sets which are I*4 (cell values are represented as an integer value stored in a four byte or 32-bit format). The maximum integer value that can be stored in a two byte format is 32767, so the highest integer value of a cell in a map stored in this fashion is 32767. The maximum integer value that can be stored in a four byte format is 2147483647, and therefore a much larger integer cell value is possible. The COUNT and DELTA data sets often generate integer cell values much higher than 32767 and therefore require the I*4 format. This becomes relevant when discussing the interface with MOSS/MAPS.

Restart capability

The COUNT and DIRECT programs contain a restart capability that permits resumption of processing if the program stopped because of insufficient disk space, or any other reason. Enter a 1 (one) to restart the process. Enter a 0 (zero) to begin the program afresh. This capability has not been tested.

Information messages

Many of the programs are iterative and report the completion of each iteration for user information. CONCAVE prints a message as it initializes each box, and SEED reports how many basin starts it seeded. In addition various error messages appear.

Program Limitations

The programs limit the number of samples (columns) to 4000. CONCAVE limits BOXNL and BOXNS to 400, or the row and column size of a rowing window. The PPTABLE program limits its pour point table entries to 2000. If you encounter the pour point table limit indicated by a "STOP 72" message, it is possible to process the data set in pieces. The RSNAP program limits the threshold distance to 50 cells in the x and y direction and does not permit movement of more than 999 points.

MOSS/MAPS Interfacing

The Hydrologic Terrain Analysis Software (HTAS) interfaces with MOSS/MAPS as follows.

- The MAPSTOIDIMS command permits conversion of a MAPS map into IDIMS format (a sequential access format). A CONVERT program converts the IDIMS data into the direct access format used by the HTAS.
- Use a reverse path to bring an HTAS processed map into MAPS. The CONVERT program transfers the MAPS file it from "direct" to IDIMS format, and then the MAPS IMPORT command, WORD option, imports the map into MOSS/MAPS.

NOTE:

*All the raster maps produced by the HTAS use the I*2 (integer * 2 bytes) format, with the exception of the flow accumulation map which has the I*4 (integer * 4 bytes) format. Currently, the MAPS IMPORT command only imports I*2 data, with the highest allowable integer number being 32768. There is currently an improved version of IMPORT, included with the HTAS package, which permits conversion of I*4 files into MAPS format as real numbers rather than integer cell value maps.*

Automated Hydrologic Terrain Analysis Concept

Influence of terrain morphology on water flow

As rainwater falls on the landscape, the morphology of the terrain is the major, if not the only determinant of which way the water flows. For the purpose of this discussion, landscape morphology includes all the macroscopic details of the shape of the surface. Surface factors that affect water flow also include the obstructive effect of vegetation cover, the infiltrative capacity and moisture content of soil, the presence of cracks or fissures in rocks and artificially made obstacles and barriers. Although some of their aspects could be related to surface morphology, these factors include physical, biological and chemical processes which, while influencing water flow, are not directly related to the gross shape of the terrain. This manual does not discuss these factors or the factors affecting water flow that relate to the processes occurring underneath the surface.

Elevation data and their resolution

Elevation contour maps, digital elevation models (DEMs) and digital terrain models of various scales and resolutions, provide basic information about the general, macroscopic trends in the shape of the landscape surfaces. A typical USGS digital elevation model has a resolution of 30x30 meters and clearly loses a significant amount of information about the detail of the surface when only one number represents a square area with a side of 98.4 feet. Therefore, all information obtained through HTAS processing with data of this resolution provides only general trends and approximations of what actually occurs, or what might occur. The HTAS only provides information on water flow based on the gross shape of the landscape, within the resolution of the data provided, and with the assumption that an unlimited supply of water runs over an essentially impermeable terrain. To perform realistic modeling of surface hydrologic processes we must combine the information obtained using HTAS with other data and processing.

Filling depressions on the landscape

The landscape often has depressions where the water pools until it finally overflows and then continues to pour in the direction determined by the terrain and other landscape factors. Imagine a tilted cup into which you are pouring water. If we have an unlimited supply of water, the cup eventually fills and finally water flows out at the lowest point on the edge of the cup. Therefore, to route water flow beyond depressions using the HTAS it is first necessary to fill them.

NOTE:

In reality, such complete filling of a sink might never occur. In dry areas with slight rainfall the water might not overflow a large depression but pond in the depression and infiltrate the soil. Such depressions, depending on the local soil and geology, might become recharge locations for an aquifer or sediment collection areas.

The HTAS contains programs which fill depressions on the surface of a DEM. Depressions found in the DEMs reflect natural conditions on the ground or imperfections in the model itself. Generally, sinks or pits where only one cell has a value lower than the surrounding cells reflects an imperfection in the DEM, however, there are cases, for example in glacial or karst areas, where these pits may reflect natural features. Multi-cell depressions are more likely to reflect natural features. First hand knowledge of field conditions is very important when interpreting the results of the depression-filling process.

The program that deals with single cell sinks is FILLSNGL, which raises the value of the depressed cell to the value of its lowest immediate neighbor in a 3x3 cell "window". The depressed cell is at the center of the window which includes its nine immediate neighbors. Figure 1 shows single cell depressions that were found and filled using FILLSNGL in the Digital Elevation Model for the 7.5 minute Sagebrush Hill quadrangle.

Figure 1: Stream network for a section of the Sagebrush Hill Quadrangle, Colorado, with single cell sinks filled using the FILLSNGL program.

The second program used to fill depressions, CONCAVE, deals with large, multi-celled depressions in the model. The program requires the user to specify the size of the window and an overlap area in terms of rows and columns. The size of the depression must be smaller than the size of the overlap for program to fill the depression. Figure 2 shows larger depressions found and filled using CONCAVE for the same quadrangle.

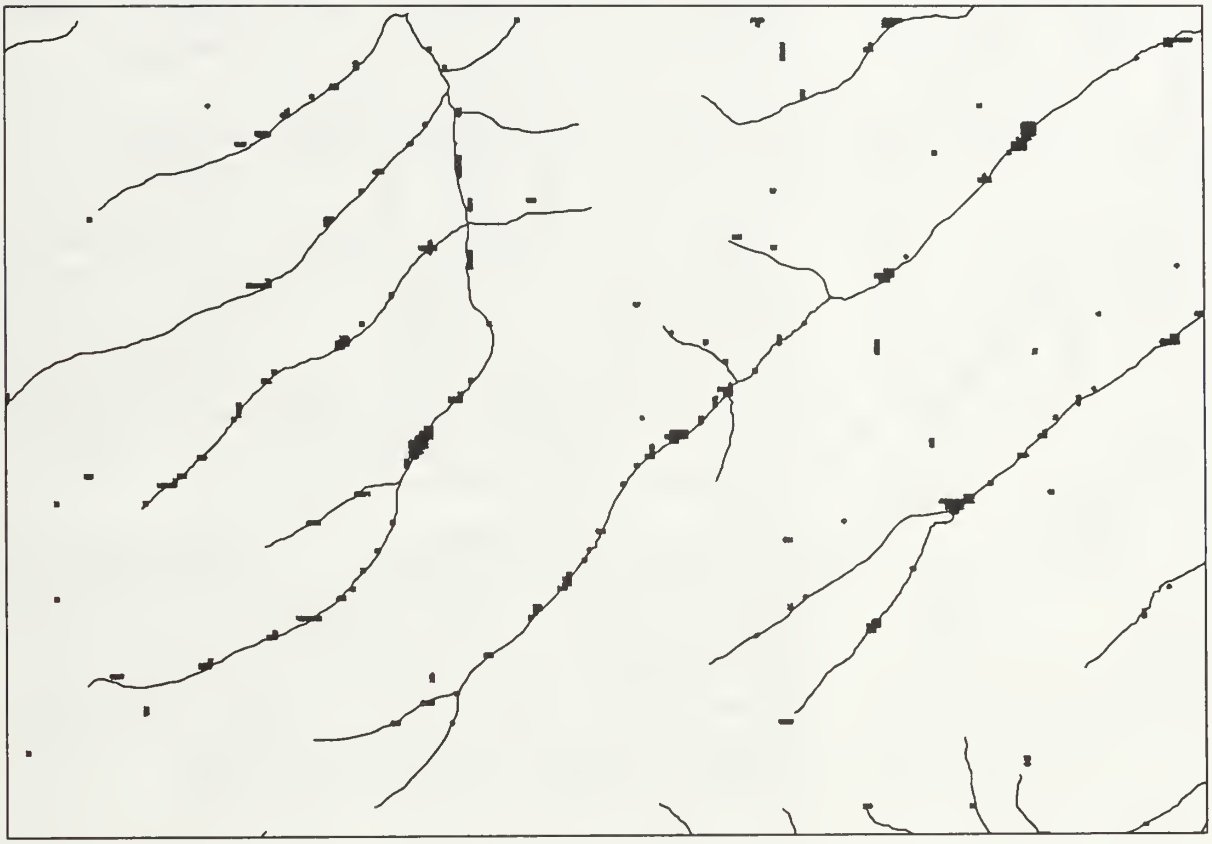

Figure 2: *Stream network for a section of the Sagebrush Hill Quadrangle, Colorado, with large depressions filled using the CONCAVE program.*

Determining flow direction

Once HTAS programs fill the depressions in the DEM, it is possible to route the water completely across the landscape and discover the direction in which it flows on the depressionless surface. The program DIRECT provided with the HTAS calculates flow directions on the depressionless surface while paying special attention to connectivity between cells. One of the eight possible directions to adjacent cells at the north, northeast, east, southeast, south, southwest, west, and northwest of a particular cell is assigned to that cell. Based on this information it becomes possible to calculate flow accumulation.

Flow accumulation and drainage pattern development

Drainage patterns develop when the rate of rainfall exceeds the rate of infiltration, causing the depressions on the surface to fill and overflow forming a thin sheet of water that flows across the landscape. This runoff takes the path of least resistance and gains velocity. It picks up soil particles and creates small channels, so that the surface of the ground exhibits, on a miniature scale, the drainage pattern of a watershed by forming rills. Finally a fluctuating drainage pattern develops throughout the entire catchment which includes rills, channels, ephemeral and perennial streams, and finally rivers.

The flow accumulation program COUNT in the HTAS permits approximate delineation of drainage patterns from DEMs based on flow directions established by the information on the gross shape of the landscape. Using the flow direction data set the program evaluates how many other cells are connected and flow into a particular cell. Therefore, the value of each cell in a flow accumulation, or flow count map, is equivalent to the number of cells that flow into this particular cell.

Since a DEM provides only a gross representation of the landscape, HTAS identifies flow patterns based only on the general shape of the terrain. In addition, it does not consider the influence of other environmental factors, including microrelief. The program, however, predicts flow patterns with surprising accuracy, particularly in areas of high relief. On large flat areas the influence of minor variations in the shape of the land which do not show up in DEMs becomes more important, and the program is subject to a greater degree of error.

Figure 3 shows the drainage pattern detected by the program in

a high relief terrain in a section of the Sagebrush Hill quadrangle. When the stream network information derived from a USGS Digital Line Graph overlays the modeled patterns, we see the close correspondence between the two data sets.

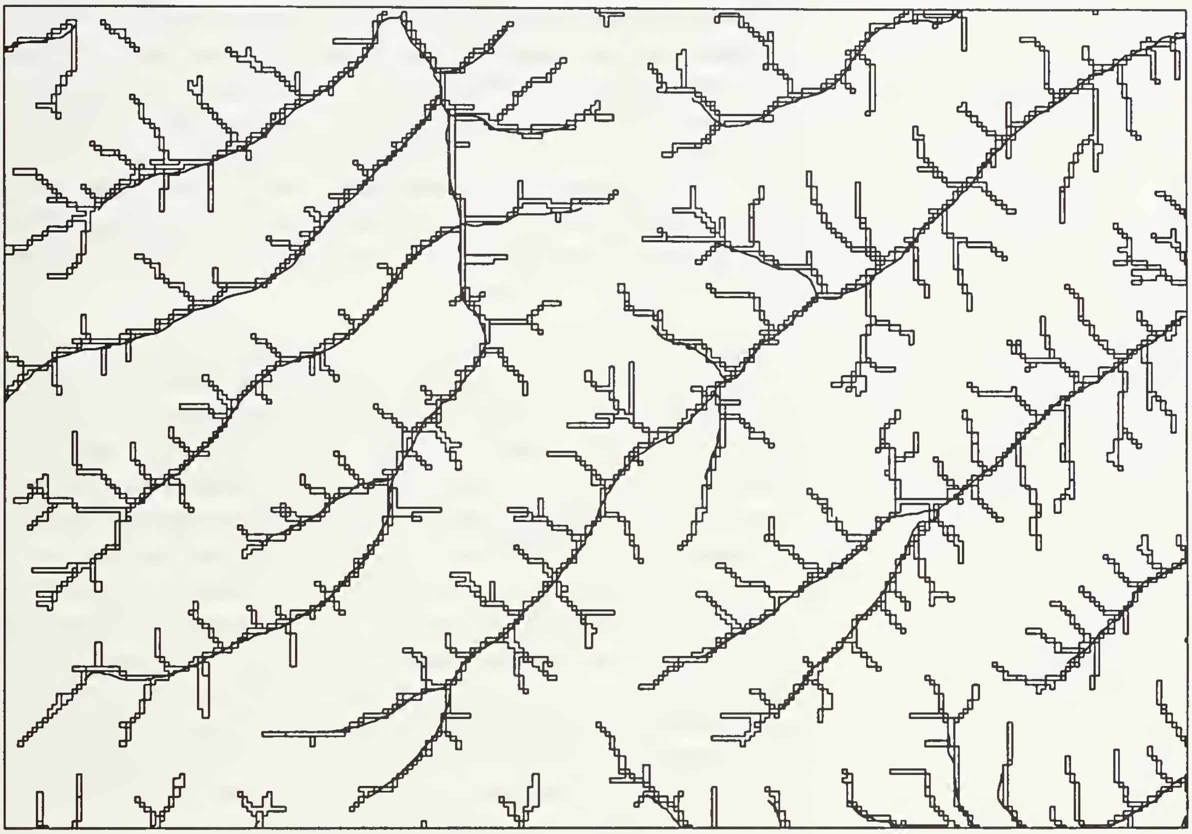

Figure 3: *DLG stream data (dark continuous lines) overlay the modeled drainage patterns which include potential and actual channels from the Sagebrush Hill quadrangle.*

The modeled data show locations of a likely drainage pattern based on gross morphology of the surface, and should be treated with caution when the areas modeled have low relief. The modeled data do not replace stream network information obtained from aerial photographic surveys, but the models are very useful for areas where there are no other data sources available.

Watershed boundary delineations

A watershed, drainage basin, catchment, or a contributing area is an area of land where water flows toward a particular location. That location can be a dam, a lake, or simply a pour point for a particular watershed. You can divide a watershed into subwatersheds. Generally, this division exists at a point where a tributary stream enters another stream in a drainage network. The total of specific subwatersheds for all of the tributaries of a particular main stream constitutes the drainage basin for the main stream. It is, however, possible to delineate a catchment area for any point on the landscape, as long as the shape of the land is such that there is water flowing towards that point. The capabilities of HTAS do not limit analysis to pour points at the nodes of a drainage network.

Watershed delineation with the HTAS identifies all the cells flowing into a particular pour point, line (e.g., dam), or an area (e.g., reservoir) as belonging to a single watershed. Based on the filled DEM, flow direction, and flow accumulation data sets obtained through prior processing,the HTA Software permits delineation of watershed and subwatershed boundaries both in a manual and automated fashion. The automated method selects pour points for possible watersheds based on a user-selected value of flow accumulation, which is called a threshold value. The manual method permits the user to select pour points, linear or polygonal (area) features, for which they desire to delineate a watershed. Both cases require creation of a "seed" or "starter" map; the word "seed" here being synonymous with the representation in a cell map of a point, line or polygon for which a watershed is delineated.

Figures 4, 5, 6 show watersheds generated for points, lines and polygons representing watershed outlets, hypothetical dams and reservoirs. **Figure 7** shows the watersheds generated for a threshold value of 3000 for the Sagebrush Hill quadrangle. The delineated watersheds do not reach the edges of the DEM, an option offered with the HTAS.

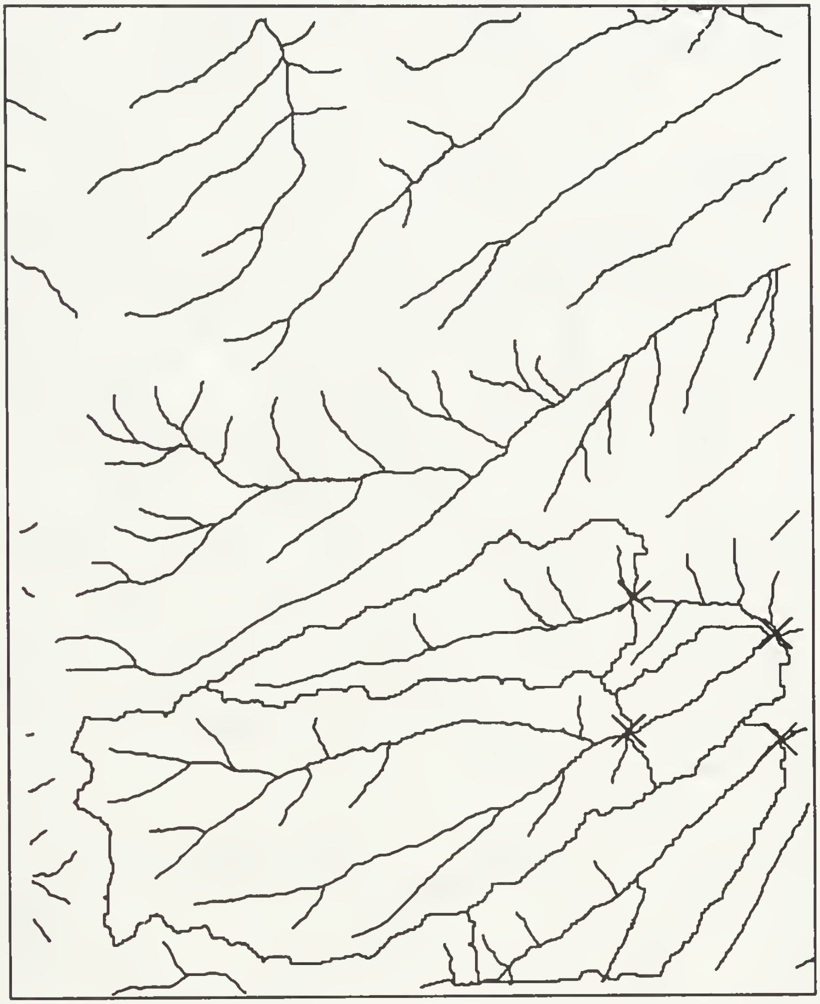

Figure 4. *Watersheds delineated for user-selected pour points.*

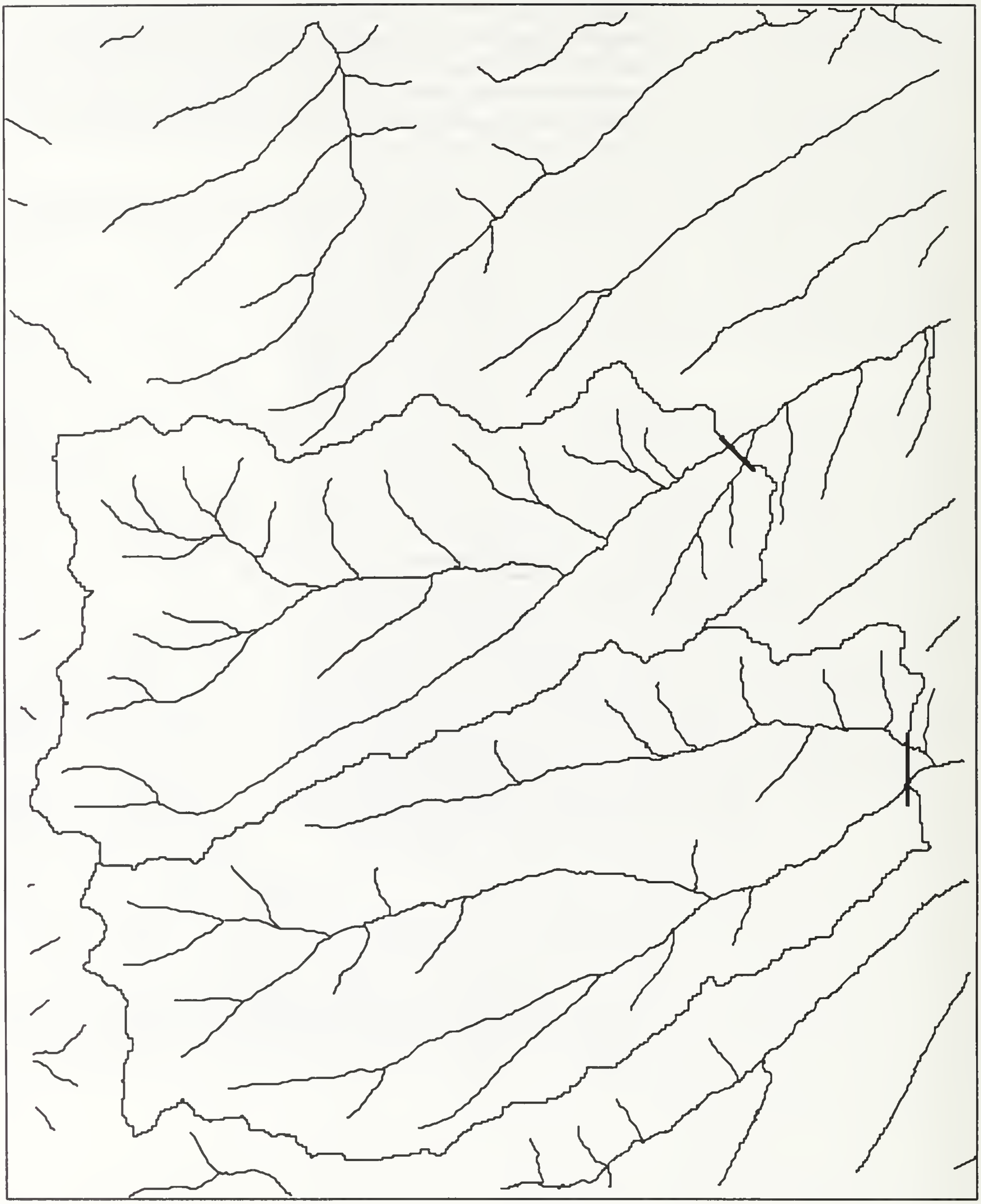

Figure 5. *Watersheds delineated for user-selected linear features.*

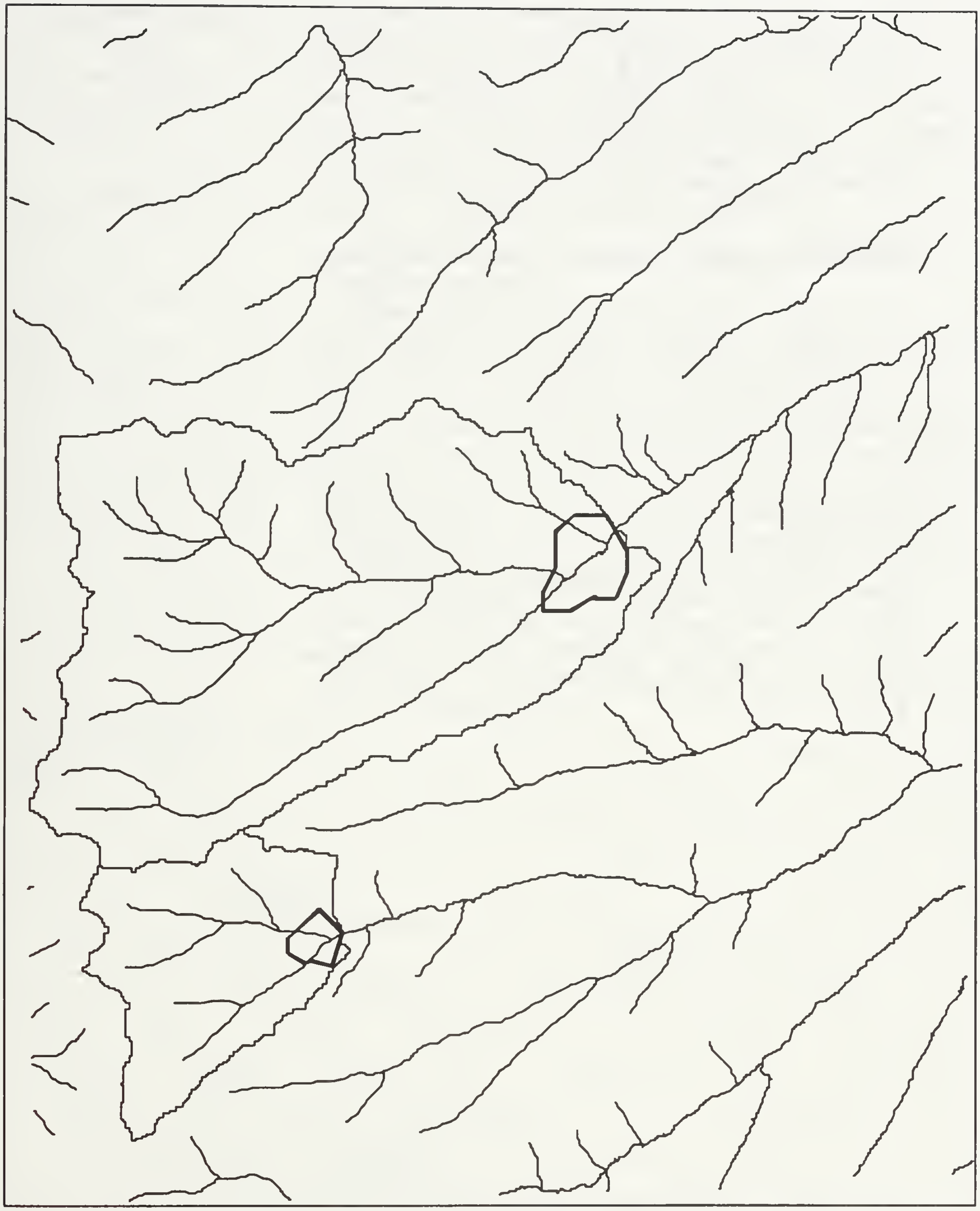

Figure 6. *Watersheds delineated for user-selected reservoirs.*

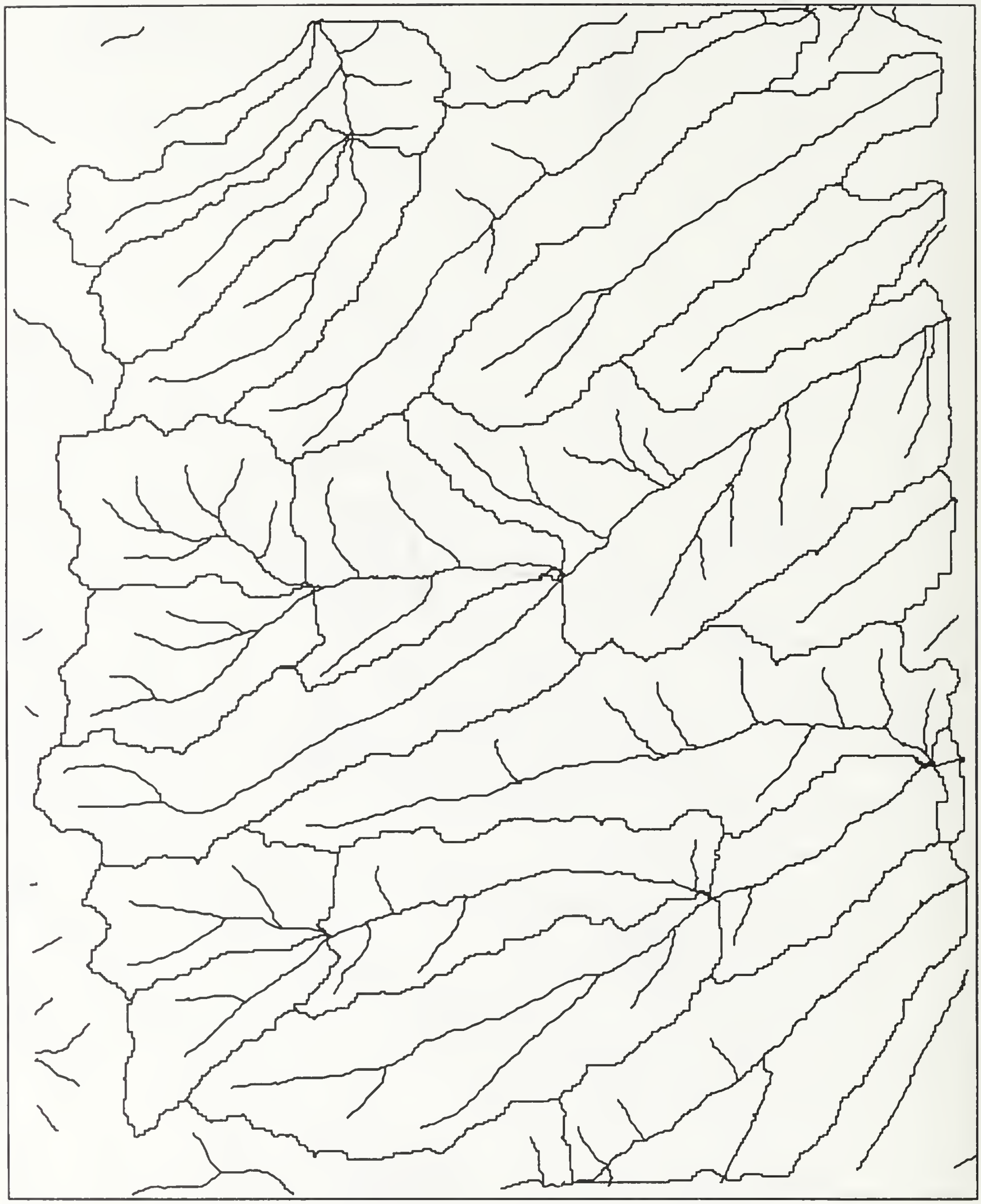

Figure 7. *Automatically delineated subwatersheds using the threshold values of 3000.*

Overland flow path delineation

Another option of the HTAS calculates and delineates the steepest overland path from a point or a set of points on the landscape. The program OVERLAND utilizes a flow direction file and a mask file similar to a seed file, which identifies points on the landscape from which to delineate the path. Figure 8 provides an example of overland paths calculated for three points in the Sagebrush Hill quadrangle.

Mapping local minima and another method for development of a drainage network

The program MINIM, when used on the elevation model, permits identification of the local minima, or cells that have a lower elevation value than the surrounding cells in a 3x3 cell window. This program also permits identification of flat areas where the central cell has the same value as all the surrounding cells in a 3x3 window. When the data set produced by MINIM is processed using OVERLAND, the OVERLAND program traces the overland paths for all these cells using the flow direction data set. The program marks all the cells into which a cell of the MINIM set drains until it reaches another cell of the MINIM set that is on the path. The result is the image of a drainage network based on the elevation data set. This is a second method for creating a drainage network, since the drainage pattern can also be delineated using the flow accumulation data set as described before.

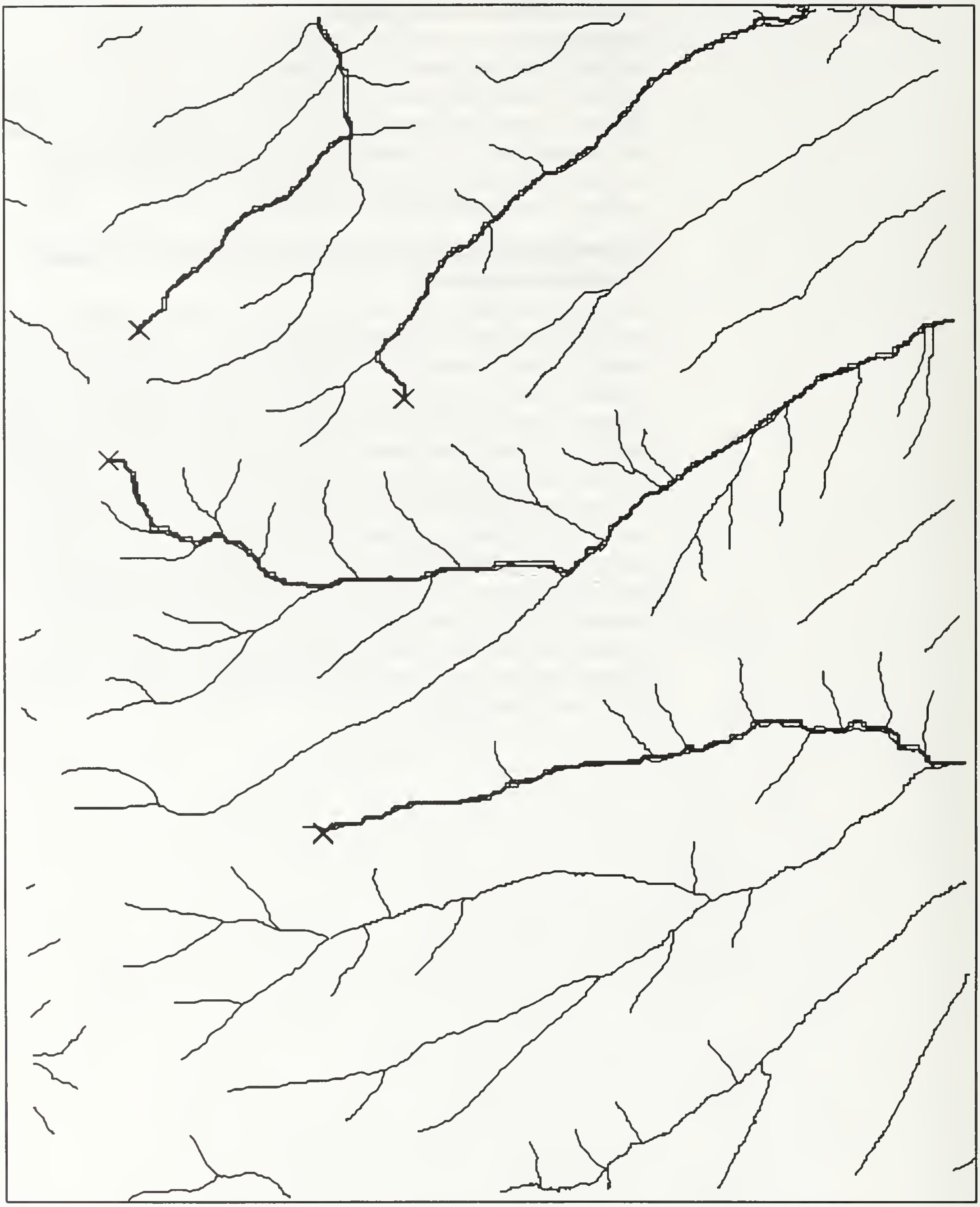

***Figure 8**. Steepest overland paths from point sources calculated using the OVERLAND program join with streams.*

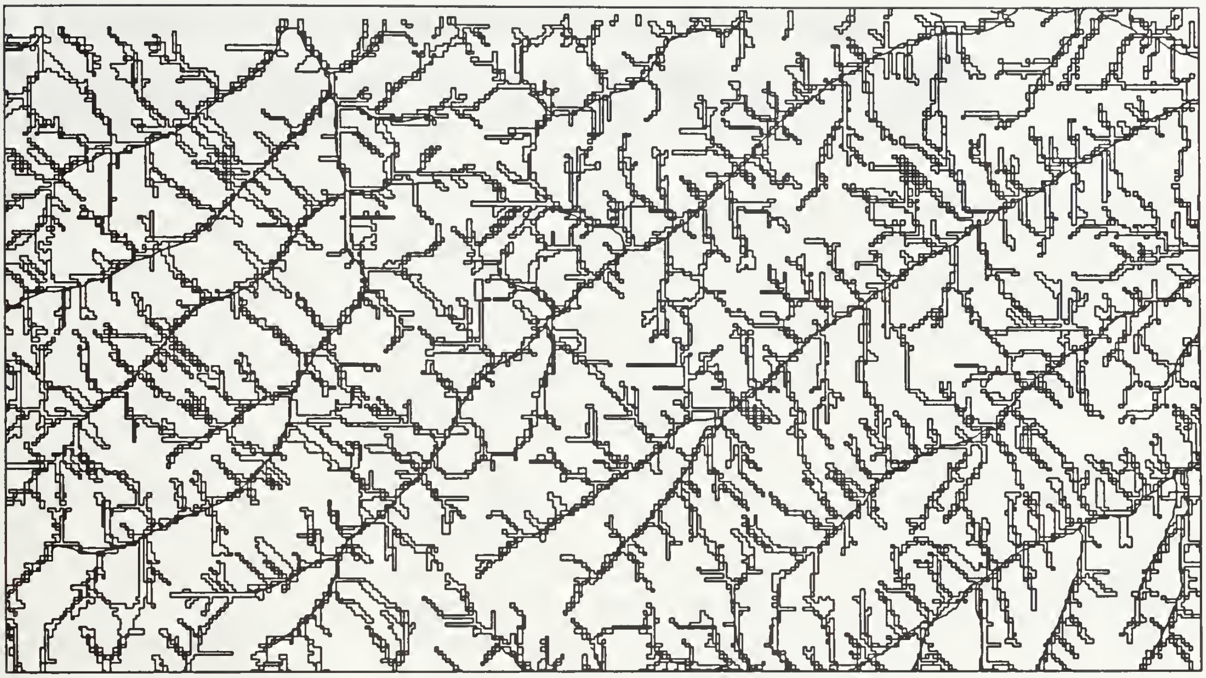

Figure 9. *The drainage network data set generated using the MINIM and OVERLAND programs with the DLG stream data OVERLAND.*

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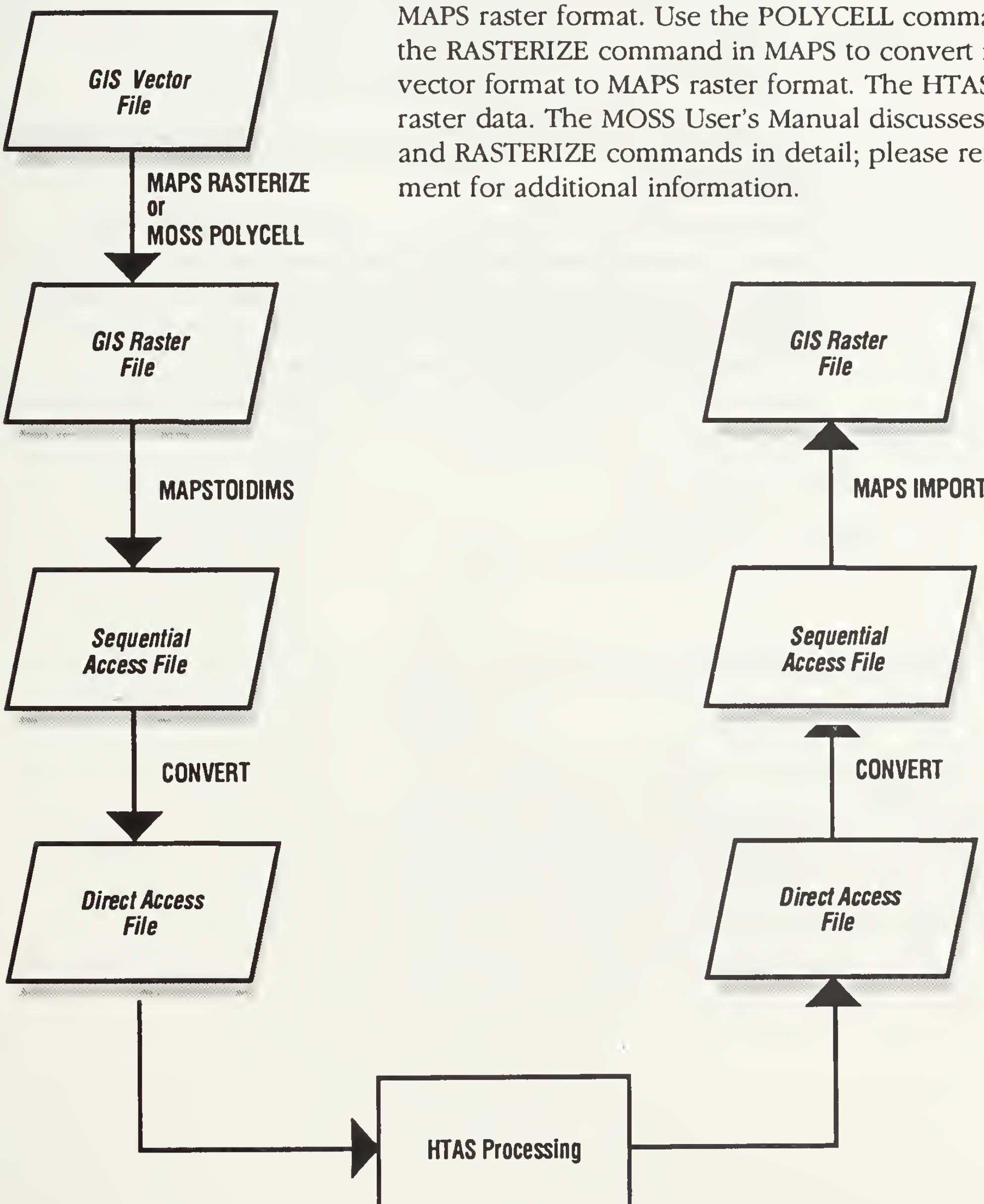
I. Convert and transfer files between MOSS/MAPS and the HTAS

The conversion and transfer of files between GIS and HTAS requires several steps and is somewhat cumbersome. In the future, HTAS will potentially integrate MOSS/MAPS capabilities which negates the need for file transfer between the two formats. Currently conversion and transfer use MAPSTOIDIMS and CONVERT commands, utilities which are executed at the Primos level, and the MAPS IMPORT command.

Maps exist or can be generated in MOSS vector format and MAPS raster format. Use the POLYCELL command in MOSS or the RASTERIZE command in MAPS to convert maps from MOSS vector format to MAPS raster format. The HTAS works only with raster data. The MOSS User's Manual discusses the POLYCELL and RASTERIZE commands in detail; please refer to that document for additional information.



STEP 1 Converting MAPS format maps into sequential access raster format (IDIMS) maps.

Use the MAPSTOIDIMS program to convert a MAPS map into a sequential access raster transfer format (IDIMS format named for the image processing system, IDIMS, which BLM has been using). MAPSTOIDIMS, an operating system (PRIMOS) level utility, converts raster files in MAPS format into the sequential access raster transfer format (IDIMS format). Originally written to convert and write files to tape, it also converts and writes files to disk by using defaults. MAPSTOIDIMS creates files with .16 and .TH suffixes after the name of the input file. The .16 files contain the raster files used for processing, while the .TH files contain information about various parameters of the master file such as the number of rows and columns or coordinates of the Minimum Bounding Rectangle (MBR) of the map (the window of the map) to which the user may refer.

WARNING:

MAPSTOIDIMS works only with 16-bit (word length) integer data; however, some of the MAPS real number files might be 32-bit (double word) data. To correct this problem use the FUNCTION command INTEGER option in MAPS to convert the real number 32-bit map into an integer 16-bit map.

```
OK, MAPSTOIDIMS
                 MAPS TO IDIMS CONVERSION
 Enter macro file name to execute file copy
  ( Default is TMCOPY )
<CR>
 Enter tape drive name MT0 or MT1 ( Default = MT0 )
<CR>
 Enter tape drive density (800, 1600 or 6250; Default = 1600 ) :
 How many maps are already on this tape ?
:<CR>
 Please enter the DIRECTORY (under MOSSDATA) or WORK
 and the .DT (project master or POLYGON :
 i.e., WOLSAG WOLSAG.DT  or  WORK POLYGON.DT
: WOLSAG 32 WOLSAG32.DT
Enter map name ( CR = End )
: DEMFILE (name of a MAPS map)
 Map- DEMFILE          has been processed.
Enter map name ( CR = End )
:<CR>
  * INSTRUCTIONS TO COMPLETE MAPSTOIDIMS *

   1) List out the .TH file created in the
      same directory that the MAPSTOIDIMS was
      executed (SPOOL or SLIST on the PRIME).
      This file contains the MBR, cell size,
      and projection criteria of the file,
      and needs to accompany the TAPE
      transferred to IDIMS

   2) Run the macro called TMCOPY to transfer
      the cell file to magnetic tape:
      •         Mount the tape
      •         Run TMCOPY (CPL TMCOPY)
    MAPSTOIDIMS completed.
**** STOP
```

NOTE:

The necessity for conversion and transfer of map data via the sequential access raster transfer (IDIMS) format rests on the fact that at this stage the system is available only on PRIMOS, and no programming additions, except for minor changes in the MAPS IMPORT command are anticipated at this time. In the future, HTAS will contain more direct interfaces should funds become available for further improvements.

STEP 2 Converting sequential access raster transfer (IDIMS) format maps into direct access format maps used in the HTAS.

After converting the data into the IDIMS format, it must be converted again into direct access format which the HTAS uses. Use the CONVERT program as follows to accomplish this task.

```
OK, R CONVERT
  Conversion desired (0=I*2 transfer-to-direct, 1=I*2 or
    I*4 direct-to-transfer):
0
  Transfer DEM input image name:
DEM.MAP.16
  Direct access output DEM image:
DEM.MAP
  Lines in image:
472
  Samples in image:
369
  Converted          200 lines
  Converted          400 lines
**** STOP
```

STEP 3 Processing direct access format maps in the HTAS.

Once the data are converted into the direct access format, any of the HTAS programs can use the data set. The HTAS Reference Manual contains an alphabetic listing of each program and a description of specific hydrologic modeling applications appear in the following parts of the HTAS User's Manual.

STEP 4 Converting direct access format maps produced by the HTAS processing into sequential access raster transfer (IDIMS) format.

To bring the data back into MAPS, convert the map into IDIMS format using the program CONVERT again. An example of converting from direct to sequential access raster transfer (IDIMS) format follows.

```
OK, R CONVERT
  Conversion desired (0=I*2 transfer-to-direct, 1=I*2 or
   I*4 direct-to-transfer):
1
  Direct access input image name:
SHED.MAP
  Transfer output image name:
SHED.MAP.16
  Direct-to-transfer data type (2=I*2, 4=I*4):
2
  Lines in image:
472
  Samples in image:
369
  Converted            200 lines
  Converted            400 lines
**** STOP
```

NOTE:

*The flow accumulation set produced by the COUNT program produces an I*4 map file. To convert I*4 files into the sequential access raster transfer (IDIMS) format, select option 4 in the "Direct-to-transfer" data type prompt.*

STEP 5 Importing sequential access raster transfer (IDIMS) format maps into the Map Analysis and Processing System (MAPS) format.

After the map file is converted to the IDIMS format, use the MAPS IMPORT command to bring the map into the MAPS GIS. The original IMPORT permits importation of word length or I*2 maps only. The new version included with this software package contains the capability to bring "double word" or I*4 maps as real number maps into the MAPS GIS.

Below is an example of how the MAPS IMPORT command works with the I*2 maps; for the import I*4 maps, use the "DOUBLEWORD" instead of the "WORD" option in the new version of IMPORT. The "DOUBLEWORD" option permits importation of type 8 maps only.

```
?
IMPORT WATERSHED.16 FORMAT IDIMS WORD FOR WATERSHED TYPE 7
 ENTER THE FOLLOWING INFORMATION FOR INPUT MAP
 NUMBER OF ROWS ?
472
 NUMBER OF COLUMNS ?
369
 CELL HEIGHT (IN METERS) ?
30
 CELL WIDTH (IN METERS) ?
30
 ENTER THE MINIMUM BOUNDING RECTANGLE
 MINIMUM X (WEST) ?
702750
 MAXIMUM X (EAST) ?
713820
 MINIMUM Y (SOUTH) ?
4416390
 MAXIMUM Y (NORTH) ?
4430550
 ENTER MAP PROJECTION INFORMATION
 PROJECTION(0-20) ?
1
 ELLIPSOID(0-19) ?
0
 LONGITUDE OF ANY POINT WITHIN THE UTM ZONE ?
-109
 LATITUDE OF ANY POINT WITHIN UTM ZONE   12 ?
35
 ENTER MAP DESCRIPTION INFORMATION
 MAP DESCRIPTION ?
WATERSHEDS BASED ON THRESHOLD OF 3000
 STUDY AREA ?
WOLSAG
 PROJECTION DESCRIPTION ?
UTM
 DATE ?
10/01/92
 SOURCE ?
J.BLASZCZYNSKI
 VINTAGE ?
1992
OK  IMPORTED FOR WATERSHED
```

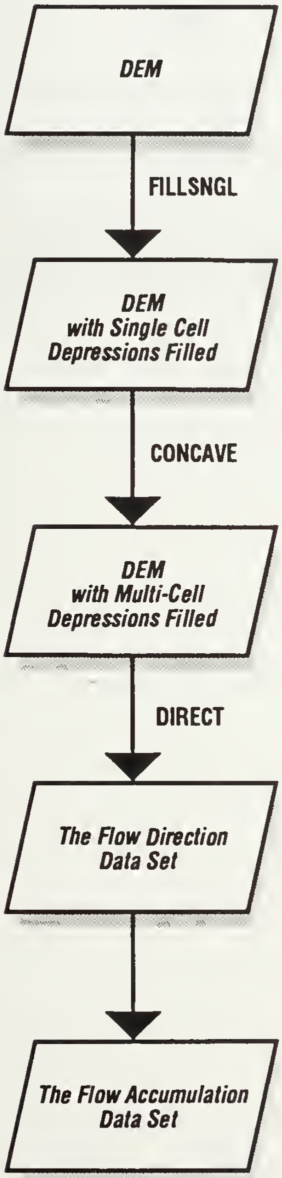
NOTE:

Once the map is imported into the MAPS GIS it becomes available for use as a data layer in analysis and cartographic modeling performed using MAPS capabilities. The final chapter of this manual briefly discusses these potential applications.

Terrain Data
Conditioning Procedures

S. Jenson refers to the aspects of HTAS processing that result in a depressionless DEM, a flow direction data set and a flow accumulation data set, as the conditioning procedures because they produce the data sets that are of general utility for all subsequent modeling.

STEP 1 Developing a depressionless DEM



HTAS provides two programs which fill depressions in a DEM to determine the flow of water to the edge of the data set across the modeled terrain. The first program, FILLSNGL fills only the single celled depressions which are usually a result of errors in the DEM. The second program, CONCAVE, fills multi-cell depressions that usually represent the actual shape of the terrain.

FILLSNGL processes data using a 3x3 cell window, and raises the value of the center cell to the value of the lowest of its neighbors. CONCAVE processes the data using overlapping windows of user specified dimensions, i.e., size of the window in lines (rows) and samples (columns) and size of the overlap. The size of the overlap must be greater than that of the depression being filled.

This process results in a depressionless DEM where each cell is a part of at least one monotonically decreasing path of cells that leads to the edge of the data set. This path consists of cells that are adjacent horizontally, vertically or diagonally in an eight-way connectedness and that steadily decrease in elevation value toward the edge of the data set.

Since both FILLSNGL and CONCAVE read from and write to the same file, keep a copy of the original DEM in the special case where flow routing with depressions present becomes important. While CONCAVE fills all the depressions, it is useful to execute FILLSNGL first and keep a copy of the product to clearly distinguishing between single-cell and multi-cell depressions.

For more details on the programs refer to the HTAS User's Reference Manual.

STEP 1A Executing FILLSNGL

To execute FILLSNGL start at that directory where the executable version of the program FILLSNGL.RUN resides by typing R FILLSNGL, or identify the path to the program from the current directory by typing R (pathname)>FILLSNGL. The inputs to the program include the number of lines or rows (NL), the number of samples or columns (NS), the name of the unprocessed, original elevation file in single quotes (TOPO FILE) which is the input and the file to which the output is written, and the name of the system in single quotes, i.e., 'PRIME' (SYSTEM).

```
OK, R FILLSNGL
 ENTER NL,NS,LEV FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'DEM.MAP','PRIME'
  Open as a Prime direct access file, ns =     369
 DEM.MAP
   opened successfully
**** STOP
```

NOTE:
FILLSNGL reads from and writes to the same file, therefore keep the original file in the HTAS format and use a copy for FILLSNGL processing.

STEP 1B Executing CONCAVE

To execute CONCAVE start at that directory where the executable version of the program CONCAVE.R resides by typing R CONCAVE, or identify the path to the program from the current directory by typing R (pathname)>CONCAVE. The inputs to the program include the number of lines or rows (NL), the number of samples or columns (NS), window size in lines or rows (BOXNL), window size in samples or columns (BOXNS), overlap between windows (OVERLAP), the name of the elevation file in single quotes (LEV FILE), and the name of the system in single quotes, i.e., 'PRIME' (SYSTEM).

NOTE:

CONCAVE reads from and writes to the same file, therefore keep the original file in the HTAS format and use a copy for CONCAVE processing.

```
OK, R CONCAVE
 ENTER NL,NS,BOXNL,BOXNS,OVERLAP,LEV FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'100,100,60,'CONCAVE.MAP','PRIME'
  System = PRIME
  Open as a Prime direct access file, ns =      369
 SGHL.CONCAVE
   opened successfully
  SL =        1
  SL =       41
  SL =       81
  SL =      121
  SL =      161
  SL =      201
  SL =      241
  SL =      281
  SL =      321
  SL =      361
  SL =      401
  SL =      441
**** STOP
```

STEP 2 Developing a flow direction data set.

The HTAS program DIRECT creates the flow direction data set and encodes, for each cell of the DEM, the direction in which the water flows out of that cell. The following schematic illustrates the directions of water flow as they are encoded in the flow direction map.

64(NW)	128(N)	1(NE)
32(W)	center	2(E)
16(SW)	8(S)	4(SE)

Although the flow direction data set is created as part of the conditioning stage for delineating watersheds, its also assists in visualizing general flow patterns on the landscape when displayed. Differing from the maps created by the ASPECT command in MAPS, this data set describes the direction of water flow in the eight-connected cells within a nine cell neighborhood, rather than calculating the directions in which the slope of the cell faces. Apply the DIRECT command to either an unfilled DEM or to a filled DEM (see FILLSNGL and CONCAVE). When applied to an unfilled or partially filled DEM, the flow direction data set contains negative numbers to represent the cells for which the flow could not be calculated. When applied to a completely filled DEM, the program assigns positive flow directions to each cell, which in turn allows calculation of a monotonically decreasing continuous path from each cell to the edge of the DEM. For more details on processing in DIRECT see the appropriate section in the HTAS User's Manual.

To execute DIRECT start at that directory where the executable version of the program DIRECT.RUN resides by typing R DIRECT, or identify the path to the program from the current directory by typing R (pathname)>DIRECT. The inputs to the program include the number of lines or rows (NL), the number of samples or columns (NS), a restart option if processing interrupted (CODE 1 TO RESTART), the name of the elevation file in single quotes (LEV FILE), the name of the flow direction file in single quotes (DIR FILE), and the name of the system in single quotes, i.e., 'PRIME' (SYSTEM).

```
OK, R DIRECT
 ENTER NL,NS,CODE 1 TO RESTART,LEV FILE,DIR FILE,SYSTEM(U
   NIX,VMS,PRIME)
472,369,0,'DEM.MAP','DIRECT.MAP','PRIME'
  Open ELEV and DIR files, ns =      369
 DEM.MAP
   opened successfully
 DIRECT.MAP
   opened successfully
 DOWNWARD PASS  1FIRSTL 2LASTL  471
 UPWARD PASS    2FIRSTL 7LASTL  465
 DOWNWARD PASS  3FIRSTL 7LASTL  461
 COULD NOT SOLVE FOR ALL CELLS
**** STOP
```

STEP 3 Developing a flow accumulation data set.

Create the flow accumulation data set by executing the program COUNT. COUNT computes flow accumulation values from flow direction values. Each cell in the COUNT data set receives a value equal to the number of cells that flow into it. Cells having the flow accumulation value of zero (to which no other cells flow) generally correspond to the pattern of ridges.

Because all cells in a depressionless DEM (a product of FILLSNGL and/or CONCAVE) have a path to the data set edge, the pattern formed by highlighting cells with values higher than a given threshold value delineates a fully connected drainage network. As the threshold value is decreased, the density of the drainage network increases. COUNT is a part of the conditioning stage for delineating watersheds, however its product also has a value for delineating drainage networks and potential stream flow modeling.

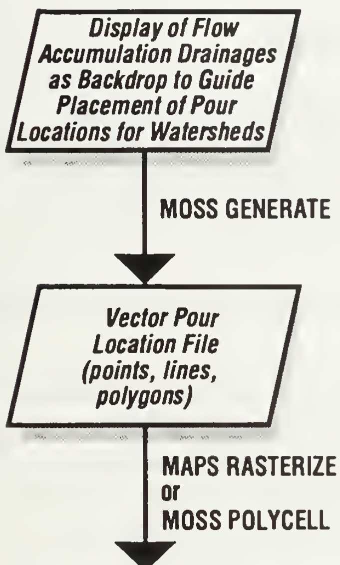
To execute COUNT start at the directory where the executable version of the program COUNT.R resides by typing R COUNT, or identify the path to the program from the current directory by typing R (pathname)>COUNT. The inputs to the program include the number of lines or rows (NL), the number of samples or columns (NS), a restart option if processing interrupted (CODE 1 TO RESTART), the name of flow direction file in single quotes (DIR FILE), the name of the flow accumulation file in single quotes (COUNT FILE), and the name of the system in single quotes, i.e., 'PRIME' (SYSTEM).

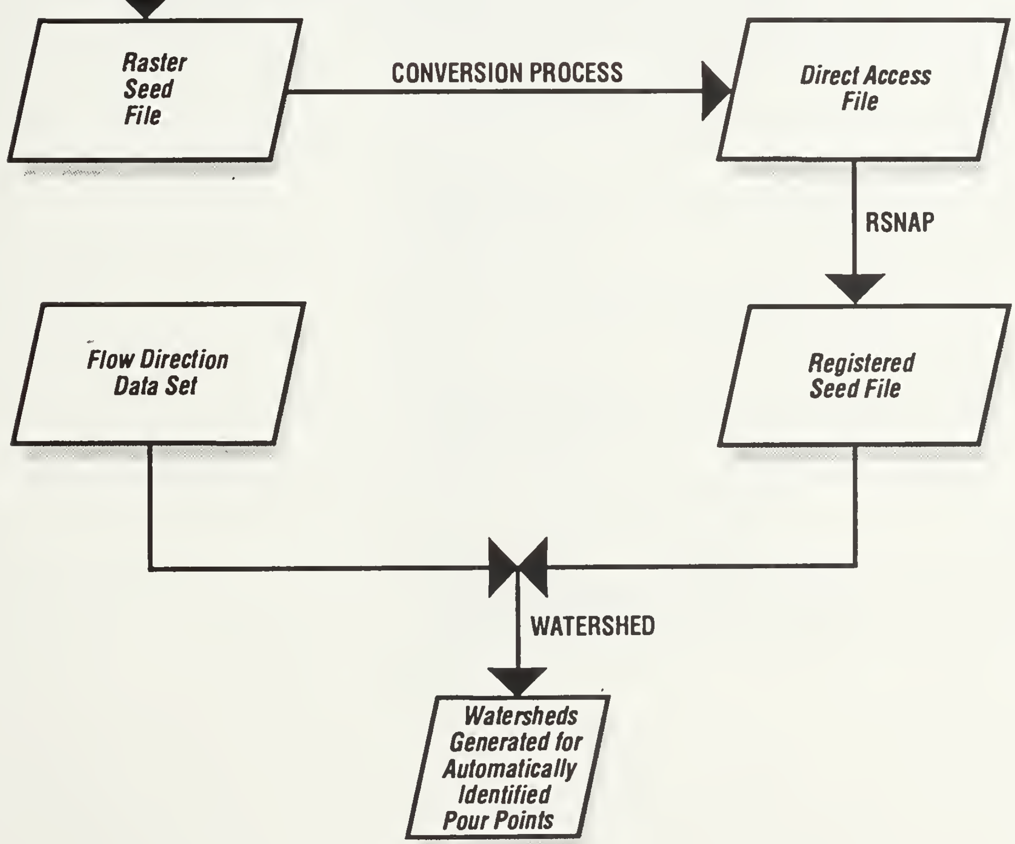
```
OK, R COUNT
  ENTER NL,NS,CODE 1 TO RESTART,DIR FILE,COUNT
  FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,0,'DIRECT.MAP','COUNT.MAP','PRIME'
 DOWNWARD PASS           1
 UPWARD PASS      2
 DOWNWARD PASS           3
 UPWARD PASS      4
 DOWNWARD PASS           5
 UPWARD PASS      6
 DOWNWARD PASS           7
 UPWARD PASS      8
 DOWNWARD PASS           9
 UPWARD PASS     10
 DOWNWARD PASS          11
 UPWARD PASS     12
 DOWNWARD PASS          13
 UPWARD PASS     14
**** STOP
```

Watersheds:
Manual Delineation

Manual delineation of watersheds requires preparation of all the data sets from the conditioning stage and generation of a pour location map. This map provides the "seed" or starter map of cells from which watersheds are delineated by identifying all the cells that flow into them. The seed cells represent pour locations for watershed pour points (outlets), linear features such as dams, or areas (polygonal features) such as reservoirs or multi-celled depressions in the elevation model, if we want to identify watersheds for the depressions.

This section discusses the complete path starting from generation of seed points, lines, or polygons in the MOSS GIS environment, to development of watershed maps in MAPS GIS format for these locations. Utilize these processes as needed, not all are necessary for all projects. This example illustrates the use of the watershed pour points, however, the process applies with only minor changes to linear and polygonal features as well.





STEP 1 Generating a flow direction map.

The flow direction data set developed as part of the conditioning stage described in Section II comprises an essential component of manual watershed delineation. Follow the procedures described in Part 2 of the HTAS User's Manual to obtain the flow direction data set.

STEP 2 Generating a vector pour location map.

The second step in the manual delineation of watersheds involves the generation of a vector pour location map in MOSS using the GENERATE command. It is useful to display flow accumulation drainages prior to generating pour locations to help place them on the drainages.

NOTE:

This manual assumes advanced knowledge of the MOSS/MAPS GIS. This document does not provide examples of the processing using MOSS/MAPS commands, except in a few instances to demonstrate the major steps of the HTAS processing. The following example uses the GENERATE command to create a point map.

```
ENTER COMMAND ?
GENERATE
 What do you wish to call the new map ?
  _______________
: SEEDS.MAPV
 Enter mapname for the template header
  ( CR=quit )
: TEMPLATE
 ENTER SOURCE OF MAP  [SOURCE      ]
:NAME THE SOURCE
 ENTER  CREATION DATE  [11/30/92]
:<CR> OR ANY OTHER DATE YOU WANT TO PUT IN
 ENTER  STUDYAREA NAME [WOLSAG  ]
:<CR> OR ANY OTHER DESCRIPTION YOU WANT TO PUT IN
 ENTER  DESCRIPTION
 [THE SEED FILE, SAGEHL QUAD]
  ____________________________________________________________ :
<CR> OR ANY OTHER DESCRIPTION YOU WANT TO PUT IN
 IS THIS HEADER INFORMATION CORRECT [Y]
: Y
 How many subjects for new map? [   20]
: 100
 Enter data type this map is to be:
      1 - Point   2 - Line   3 - Polygon
: 1
 Keyboard or Cursor input (K/C) [C]
: C
 To choose your point and enter the subject.  You may:  Quit (Q)
  (CR=Continue)
:<CR>
 Enter subject for this item [ ]
: 1
<CURSOR INPUT>
 To choose your point and enter the subject.  You may:  Quit (Q)
  (CR=Continue)
:<CR>
 Enter subject for this item [1]
: 2
<CURSOR INPUT>
 To choose your point and enter the subject.  You may:  Quit (Q)
  (CR=Continue)
:<CR>
 Enter subject for this item [2]
: 3
<CURSOR INPUT>
 To choose your point and enter the subject.  You may:  Quit (Q)
  (CR=Continue)
: Q
**** STOP
```

STEP 3 Preparing a cell (raster) seed map from the vector seed map.

The next step in the process involves preparing a cell (raster) seed map from the vector seed map. First, RASTERIZE the vector map into a type 8 raster map, and then RENUMBER the values of all the zero background cells to -1.

```
ENTER COMMAND ?
MAPS
    71 MAPS IN   WORK PROJECT POLYGON
   130 MAPS IN MASTER PROJECT WOLSAG32
 ?
WI DEM.MAP (windowing on the right basemap is essential)
 OK  WINDOWED
 ?
RASTERIZE SEEDS.MAPV HEIGHT 30 WIDTH 30 TYPE 8 FOR
  SEEDS.TEMPR
 PROCESSING  POINT  NUMBER       1
 PROCESSING  POINT  NUMBER       2
 PROCESSING  POINT  NUMBER       3
 .
 .
 .
 PROCESSING  POINT  NUMBER      79
 PROCESSING  POINT  NUMBER      80
 PROCESSING  POINT  NUMBER      81
**** STOP
 OK  RASTERIZED FOR SEEDS.TEMPR
 ?
RENUMBER SEEDS.TEMPR AS -1 TO 0 FOR SEEDS.MAPR
 OK  RENUMBERED FOR SEEDS.MAPR
```

STEP 4 Converting MAPS format seed map into direct access format used in the HTAS.

For this step use the conversion procedures outlined in Part 1 of the HTAS User's Manual. For the purposes of this description, the name of the HTAS file into which the "SEEDS.MAPR" has been converted is "SEEDS.MAP".

STEP 5 Using RSNAP to correct location of seed cells.

WARNING:

The use of RSNAP applies to pour point seed data. It has not been tested with line or polygon based seed data. With these types of data do not use RSNAP unless you have tested its effects.

RSNAP finds a cell with the nearest flow accumulation value above a user-specified flow accumulation threshold, and within a threshold distance from a manually generated seed cell. The threshold distance specified by the user identifies a value for the number of cells in the line (row) and sample (column) direction that represent the neighborhood around the seed cell. The program then snaps a manually delineated seed cell to the location of the cell it found.

The function of this program snaps the manually defined watershed pour points or seeds to the drainage patterns modeled from the DEM. When manually defining watershed pour points there is the potential for newly created seeds not to be registered to the modeled drainage patterns. For example, a pour point generated only on the basis of DLG stream data might fall slightly outside of drainage pattern derived using the HTAS. In such a case the flow accumulation value for the point is low, because it is considered to lie outside of the drainage network. Since few cells are modeled as flowing into the pour point, the program delineates only a very small watershed for this pour point. RSNAP snaps the user defined pour points to a cell on the HTAS modeled drainage pattern, so that they are properly registered to the DEM and full watersheds can be delineated.

NOTE:

RSNAP reads from and writes to the same file, therefore keep the original file in the HTAS format and use a copy for RSNAP processing. RSNAP cannot process more than 999 points.

```
OK, A RSNAP
  ENTER NL,NS,FLOW THRESHOLD,DISTANCE THRESHOLD,SEED FILE,COUNT
   FILE,SYSTEM(UNIX,VMS,PRIME)
   472,369,50,10,'SEEDS.MAP','COUNT.MAP','PRIME'
   MOVED SEED FOR  78 FROM   3,    308 TO    2,    306(2.23607     CELLS)
   MOVED SEED FOR  66 FROM   9,     51 TO   10,     51(1.00000     CELLS)
   MOVED SEED FOR   2 FROM   9,    117 TO    8,    116(1.41421     CELLS)
   MOVED SEED FOR  11 FROM  14,    356 TO   13,    356(1.00000     CELLS)
   .
   .
   .
   MOVED SEED FOR  56 FROM 416,     12 TO  417,     12(1.00000     CELLS)
   MOVED SEED FOR  63 FROM 448,    244 TO  447,    244(1.00000     CELLS)
   MOVED SEED FOR  64 FROM 459,    228 TO  460,    228(1.00000     CELLS)
 TOTAL OF       34 POINTS MOVED
       81 SEED CELLS WERE FOUND
**** STOP
```

STEP 6 Delineating watersheds for the user defined pour locations.

To delineate watersheds for the generated “seed” map, use the “seed” map with the WTRSHED command. WTRSHED finds watersheds for “seed” cells that represent user-specified or automatically assigned pour locations.

To delineate watersheds, WTRSHED utilizes both a flow direction data set and a “seed” data set. The “seed” or starter data set consists of background values of -1 in which the “seed” cell or group of cells have been inserted at the outflow points of the desired watersheds. Each start cell or group of cells contains its own unique positive value. Using the flow direction data set, WTRSHED iteratively reassigns the background values of cells in the starter data set to the value of the “seed” cell or group of cells into which the background cells flow. The flow direction map identifies the flow connectedness and direction of the background cells.

NOTE:

Since WTRSHED overwrites the seed file, the example uses “SHEDS.MAP”, a copy of “SEEDS.MAP” for easier reference. To keep better track of the intermediate products keep a copy of the unchanged seed file, particularly if disk space is not an immediate problem. However, since you already have a version of it in MAPS format and IDIMS format, this is not necessary.

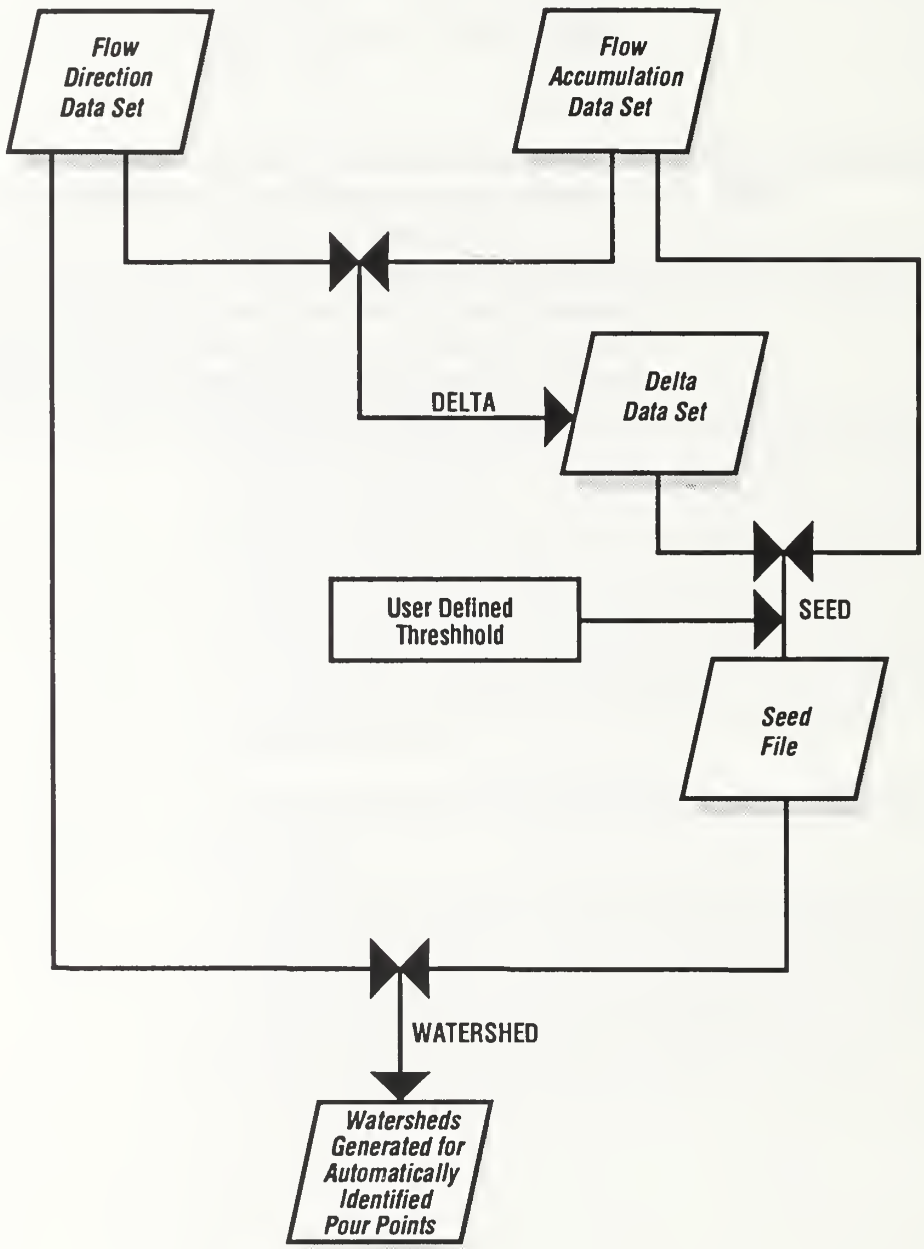
```
OK, R WTRSHED
 ENTER NL,NS,DIR FILE,MASK FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'SGHL.DIR','SGHL.SHED','PRIME'
 PASS  1
 PASS  2
 PASS  3
 PASS  4
 PASS  5
 PASS  6
 PASS  7
 PASS  8
 PASS  9
 PASS 10
 PASS 11
 PASS 12
 PASS 13
 PASS 14
**** STOP
```

STEP 7 Converting the watershed map into MAPS format.

Use the procedures described in section I of the HTAS Users' Manual. Once the map has been imported into the MAPS GIS, it becomes available for use as a data layer in analysis and cartographic modeling using MAPS capabilities. The last chapter of this manual briefly discusses potential applications.

Watersheds:
Automatic Delineation

Automatic delineation of watersheds differs from manual delineation in that the watershed pour point or "seed" map is created through automatic rather than manual means. Additionally, it is not possible to generate multi-cell pour locations representing linear or polygonal features using the automated method.



STEP 1 **Generating the flow direction and flow accumulation data sets in the conditioning stage.**

Two of the data sets generated in the conditioning stage (Part 2), namely the flow direction data set and the flow accumulation data set are essential for this procedure. Once these sets are generated, create a delta data set using the DELTA command.

STEP 2 **Identifying flow accumulation increments using the DELTA program.**

The DELTA program computes flow accumulation increments from flow accumulation (COUNT) values. The DELTA process assists in automatic delineation of watersheds, by providing one of the data sets required to automatically locate watershed pour points.

Delta value is the amount of increase in flow accumulation value in the direction of flow. Each cell contains a computed delta value derived by subtracting the flow accumulation value of a cell from the flow accumulation value of a cell into which it flows. Imagine that two cells with a flow accumulation value of 1000 flow into a single cell with a flow accumulation value of 2000. The DELTA value of each of these cells is 1000. Since both cells flow into the same cell, they form a junction of potential channels. In the area where there is no juncture of tributaries, along the stream channel, the DELTA value or the flow accumulation increment is always 1, because flow proceeds from one cell to another cell. Tributary junctures generally cause a sudden increase in flow accumulation values. Therefore, DELTA program generates a map that can help to identify flow juncture locations, and the map created by it is one of the data components used to find locations of watershed pour points using the SEED program for watershed delineation with the WTRSHED program.

The following example illustrates the use of the DELTA command.

```
OK, R DELTA
  ENTER NL,NS,DIR FILE,COUNT FILE,DELTA
   FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'DIRECT.MAP','COUNT.MAP','DELTA.MAP','PRIME'
**** STOP
```

STEP 3 Developing a seed cell data set using the SEED program.

The next step of automatic watershed delineation requires finding watershed pour points or seeds. Use the SEED program to automatically accomplish this task. The SEED program finds the starter or "seed" points for automatic watershed generation at the outlets of potential stream tributaries on the drainage pattern modeled using the HTAS. SEED accepts user input of the values (in number of cells) for the flow accumulation threshold above which the pour points of watersheds are found. It also uses flow accumulation (COUNT) values and DELTA values.

For each cell where both the flow accumulation value and the delta value are greater than the flow accumulation threshold, SEED assigns to this cell a unique positive value. This means that, for a given threshold, the program places a seed where the delta value, or a flow accumulation increment between two cells, is above that threshold, and where the flow accumulation (COUNT) value is above that threshold. The first condition effectively places the "seed" where there is a juncture or tributary relationship between two potential streams and the amount of flow input (the increment) from the streams is above the threshold. The second condition eliminates any streams which have a flow accumulation value below the threshold as being too insignificant to have "seeds," thereby eliminating minor tributaries. The cell that fits these criteria represents a pour point or a "seed" of an automatically delineated watershed and receives a positive value. The watersheds grown from each of these pour points receives the value of the "seed" when using the WTRSHED program. The background cells in the SEED data set receive value of -1.

The following example illustrates the use of the SEED command.

```
OK, R SEED
  ENTER NL,NS,THRESHOLD,EDGES,SEED FILE,DELTA FILE, COUNT
  FILE,SYSTEM(UNIX,VMS,PRIME)
  472,369,3000,1,'SEEDS.MAP','DELTA.MAP','COUNT.MAP','PRIME'
  20 BASINS WERE SEEDED
**** STOP
```

STEP 4 Delineating watersheds for the automatically derived pour point locations.

To delineate watersheds for the "seed" map generated using the SEED program, use the "seed" map as one of the inputs into the WTRSHED command. WTRSHED finds watersheds for "seed" cells that represent automatically assigned pour locations.

To delineate watersheds, WTRSHED utilizes both a flow direction data set and the "seed" data set. The "seed" or starter data set consists of background values of -1 in which "seed" cell or groups of cells have been inserted at the outflow points of the desired watersheds, and each start cell or group of cells has its own unique positive value. Using the flow direction data set, WTRSHED iteratively reassigns the background values of cells in the starter data set to the value of the "seed" cell or group of cells into which the background cells flow. The flow direction map identifies the flow connectedness and direction of the background cells.

NOTE:

Since WTRSHED overwrites the seed file, the example below uses the "SHEDS.MAP" name for easier reference instead of the HTAS seed file "SEEDS.MAP". To better track the intermediate products, keep a copy of the unchanged seed file, particularly if disk space is not an immediate problem. However, since you already have a version of it in MAPS format and IDIMS format, this is not necessary.

```
OK, R WTRSHED
 ENTER NL,NS,DIR FILE,MASK FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'SGHL.DIR','SGHL.SHED','PRIME'
 PASS  1
 PASS  2
 PASS  3
 PASS  4
 PASS  5
 PASS  6
 PASS  7
 PASS  8
 PASS  9
 PASS 10
 PASS 11
 PASS 12
 PASS 13
 PASS 14
**** STOP
```

STEP 5 Converting the watershed map into MAPS format.

Use procedures described in Part 1 of the HTAS User's Manual to convert watershed maps to MAPS format. Once the map is imported into the MAPS GIS, it becomes available as a data layer for analysis and cartographic modeling performed using MAPS capabilities. The last chapter of this manual briefly discusses these potential applications.

Delineating
Overland Paths of Flow

To delineate overland flow paths for various point sources on the landscape use a procedure similar to the procedure for manual delineation of watersheds. First, generate a starter or "seed" data set which in this case does not represent watershed pour points, but sources of flow. These sources of flow include springs or point sources of pollution. The HTAS OVERLAND program delineates the steepest path of flow along the landscape using the flow direction data set, by tracing out the cells into which the initial cell flows.

STEP 1 **Generating a flow direction map.**

The flow direction data set developed as part of the conditioning stage described in Part 2 is an essential component of automatic watershed delineation. Follow the procedures described in Part 2 of the HTAS User's Manual.

STEP 2 **Generating a vector point source map.**

The second step of the automatic delineation of watersheds involves generating a vector point source map in MOSS using the GENERATE command. This command allows the user to generate the points anywhere on the landscape.

NOTE:
This manual assumes advanced knowledge of the MOSS/MAPS GIS, and examples of the processing using MOSS/MAPS commands will not be generally provided. However, a few exceptions will be made so as to demonstrate the major steps of the HTAS processing. An example of using the GENERATE command to create a point map is as follows:

```
ENTER COMMAND ?
GENERATE
 What do you wish to call the new map ?
  _______________
: SOURCES.MAPV
 Enter mapname for the template header
  ( CR=quit )
: TEMPLATE
 ENTER SOURCE OF MAP  [SOURCE       ]
:NAME THE SOURCE
 ENTER  CREATION DATE  [11/30/92]
:<CR> OR ANY OTHER DATE YOU WANT TO PUT IN
 ENTER  STUDYAREA NAME [WOLSAG  ]
:<CR> OR ANY OTHER DESCRIPTION YOU WANT TO PUT IN
 ENTER  DESCRIPTION
 [THE POINT SOURCES FILE, SAGEHL QUAD]
  _________________________________________________________ :
<CR> OR ANY OTHER DESCRIPTION YOU WANT TO PUT IN
 IS THIS HEADER INFORMATION CORRECT [Y]
: Y
 How many subjects for new map? [   20]
:  100
 Enter data type this map is to be:
      1 - Point   2 - Line   3 - Polygon
: 1
 Keyboard or Cursor input (K/C) [C]
: C
 To choose your point and enter the subject .  You may:  Quit (Q)
   (CR=Continue)
:<CR>
 Enter subject for this item [ ]
: 1
<CURSOR INPUT>
 To choose your point and enter the subject .  You may:  Quit (Q)
   (CR=Continue)
:<CR>
 Enter subject for this item [1 ]
: 2
<CURSOR INPUT>
 To choose your point and enter the subject .  You may:  Quit (Q)
   (CR=Continue)
:<CR>
 Enter subject for this item [2]
: 3
<CURSOR INPUT>
 To choose your point and enter the subject .  You may:  Quit (Q)
   (CR=Continue)
: Q
**** STOP
```

STEP 3 Preparing a cell (raster) seed map from the vector seed map.

The next step prepares a cell (raster) point source seed map from the vector point source seed map. First RASTERIZE the vector map into a type 8 raster map, and then RENUMBER the values of all the zero background cells to -1.

```
ENTER COMMAND ?
MAPS
    71 MAPS IN   WORK PROJECT POLYGON
   130 MAPS IN MASTER PROJECT WOLSAG32
 ?
WI DEM.MAP (windowing on the right basemap is essential)
 OK  WINDOWED
 ?
RASTERIZE SOURCES.MAPV HE 30 WI 30 TYPE 8 FOR
  SOURCES.TEMPR
 PROCESSING  POINT  NUMBER      1
 PROCESSING  POINT  NUMBER      2
 PROCESSING  POINT  NUMBER      3
 .
 .
 .
 PROCESSING  POINT  NUMBER     79
 PROCESSING  POINT  NUMBER     80
 PROCESSING  POINT  NUMBER     81
**** STOP
 OK  RASTERIZED FOR SOURCES.TEMPR
 ?
RENUMBER SOURCES.TEMPR AS -1 TO 0 FOR SOURCES.MAPR
 OK  RENUMBERED FOR SOURCES.MAPR
```

STEP 4 Converting MAPS format point source map into direct access format used in the HTAS.

For this step, use the conversion procedures outlined in Part 1 of the HTAS User's Manual. For the purposes of this description, the HTAS file, SOURCES.MAPR was converted to an HTAS file named SOURCES.MAP.

STEP 5 Delineating overland paths for the user defined point sources.

To delineate overland for the generated point source map, use the point source map with the OVERLAND program. OVERLAND traces overland paths for user-specified cell(s) contained in a starter point sources data set. The program uses the flow direction data set to produce a path or paths by following the cell-to-cell linkage (how cells flow into each other) starting from the user specified cell(s) until it reaches the data set edge. The results of this process are helpful in tracking the overland path from point source of pollution into nearby streams.

```
OK, R OVERLAND
 ENTER NL,NS,DIR FILE,MASK FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'DIRECT.MAP','SOURCES.MAP','PRIME'
 PASS       1
 PASS       2
 PASS       3
 PASS       4
**** STOP
```

STEP 6 Converting the overland paths map into MAPS format.

Again, use procedures described in Part 1 of the HTAS User's Manual. Once the map is imported into the MAPS GIS, it becomes available for use as a data layer in analysis and cartographic modeling performed using MAPS capabilities. The last chapter of this manual briefly discusses potential applications.

Locating Elevation Minima & Delineating Drainage Patterns

There two ways to delineate drainage patterns using the HTAS. The first method uses the flow accumulation data set. By displaying the values of the flow accumulation map developed in the Conditioning Stage at various increments, for example 50-100, 100-999, 999-50000, a drainage pattern appears on the screen. The display of the drainage network gradually increases in complexity as the bottom threshold of flow accumulation values being displayed decrease. Using MAPS commands such as EXTRACT, extract ranges of values to obtain a network with a density that approximates the level of detail desired, for example approximating the density of a stream network derived from DLG data.

Use the programs MINIM and OVERLAND together to obtain a map of drainage patterns via an alternative method. MINIM finds all the local elevation minima, or downward inflection points in a depressionless DEM. OVERLAND uses the data set produced by MINIM to delineate drainage patterns by connecting the local minima with flow paths. According to Jenson, this method, as opposed to the flow accumulation method, produces narrow drainage paths for areas of broad, shallow valleys where the flow accumulation data set would produce a drainage network with wide lines.

STEP 1 Locating elevation minima.

To locate elevation minima, such as downward inflection points and flats, use the HTAS program MINIM. The MINIM program reads an elevation file and examines each cells neighborhood within a 3x3 window (a nine cell neighborhood). If any of the endpoints of symmetric cross-sections through the neighborhood are higher than the center, then the center cell receives a value of 2 to represent the bottom of a valley, or a V-shape on the landscape. If the cell is equal in value to all its neighbors, it is a flat and receives the value of 3. MINIM delineated cells, by identifying valley shaped areas and flats, form a crude unconnected drainage network.

```
OK, R MINIM
 ENTER NL,NS,TOPO FILE,MINIMA FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'DEM.MAP','MINIMA.MAP','PRIME'
 COMPLETED A MOREFLATS PASS
**** STOP
```

STEP 2 Delineating a drainage network.

Running the HTAS program OVERLAND on the MINIMA data set generates a map in which the overland paths for all the MINIMA cells are traced using the flow direction data set. This produces an fully connected drainage network data set.

The OVERLAND program traces overland paths for a starter data set consisting of cells assigned positive values in a background of -1. In this case, the starter data set is the MINIM data set. The program uses the flow direction map to produce paths by following the cell-to-cell linkage (how cells flow into each other) starting from the user specified cell(s) until the program reaches the data set edge.

```
OK, R OVERLAND
 ENTER NL,NS,DIR FILE,MASK FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'DIRECT.MAP','MINIM.MAP','PRIME'
 PASS 1
 PASS 2
 PASS 3
 PASS 4
**** STOP
```

Generating a Table of Watershed Pour Points

Create a table of pour points using the HTAS program PPTABLE to review the location of watershed pour points or find out their elevation. PPTABLE builds a table of pour points for watersheds. To accommodate data sets where there are internal or closed drainage patterns and where pour points are very close or equal in elevation for a watershed A to drain to either watershed B or C, the program computes all possible pour points. The table provides information on the label, elevation and location of the pour point on the map in line (row) and sample (column) format.

```
OK, R PPTABLE
 ENTER NL,NS,BASIN FILE,ELEV FILE,TABLE
  FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'SEED.MAP','DEM.MAP','PPTABLE.SEED','PRIME'
**** STOP
Example of output:
OK, SLIST PPTABLE.SEED
1        THIS IS THE COMPLETE LIST OF POUR POINTS
  SEQUENCE NO. LABEL   PAIR    ELEVATION       LINE    SAMP
    1           0/      1      2070            2        0
    2           0/      2      2151            4        0
    3           0/      3      2146            7        0
    4           0/      4      2126            7        0
  .
  .
  .
  163           55/    56      2608            448     49
  164           0/     50      2485            453      0
  165           0/     56      2381            469      0
  166           0/     54      2194            463      0
```

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HTAS Commands Reference

This part describes each of the commands used by HTAS, listing them in alphabetical order.

CONCAVE - Fills large depressions in a DEM. CONCAVE requires specifications for the size of box or window (BOXNL, BOXNS) and the dimensions by which the boxes overlap in both line (row) and sample (column) by a value specified as OVERLAP. The largest diameter of the largest depression to be filled must be less than the overlap. The size of the box (BOXNL, BOXNS) must not be greater than 400. CONCAVE is a part of the conditioning stage for delineating watersheds, however its product also has value in identifying surface depressions in the DEM. CONCAVE reads from and writes to the original DEM file, so it's good to keep a copy of the original. The following example uses a copy of the DEM file called CONCAVE.MAP.

Input parameters:

Number of lines or rows (NL),

Number of samples or columns (NS),

Window size in lines or rows (BOXNL),

Window size in samples or columns (BOXNS),

Overlap between windows (OVERLAP),

Name of the elevation file in single quotes (LEV FILE),

Name of the system in single quotes, e.g., 'PRIME' (SYSTEM)

```
OK, R CONCAVE
 ENTER NL,NS,BOXNL,BOXNS,OVERLAP,LEV FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'100,100,60,'CONCAVE.MAP','PRIME'
  System = PRIME
  Open as a Prime direct access file, ns =      369
 SGHL.CONCAVE
  opened successfully
  SL =        1
  SL =       41
  SL =       81
  SL =      121
  SL =      161
  SL =      201
  SL =      241
  SL =      281
  SL =      321
  SL =      361
  SL =      401
  SL =      441
**** STOP
```

CONVERT - Converts from and to sequential access raster transfer map file (IDIMS format) and a direct access raster map file used by the HTAS.

Input parameters:

Select transfer-to-direct (option 0) or direct-to-transfer (option 1)

If direct-to-transfer select I*2 datatype (option 2) or I*4 datatype (option 4)

Number of lines (rows)

Number of samples (columns)

Converting from sequential access raster transfer format to direct access format:

```
OK, R CONVERT
  Conversion desired (0=I*2 transfer-to-direct, 1=I*2 or
   I*4 direct-to-transfer):
0
  Transfer DEM input image name:
DEM.MAP.16
  Direct access output DEM image:
DEM.MAP
  Lines in image:
472
  Samples in image:
369
  Converted           200 lines
  Converted           400 lines
**** STOP
```

Converting from direct to sequential access raster transfer format:

```
OK, R CONVERT
  Conversion desired (0=I*2 transfer-to-direct, 1=I*2 or
   I*4 direct-to-transfer):
1
  Direct access input image name:
SHED.MAP
  Transfer output image name:
SHED.MAP.16
  Direct-to-transfer datatype (2=I*2, 4=I*4):
2
  Lines in image:
472
  Samples in image:
369
  Converted           200 lines
  Converted           400 lines
**** STOP
```

NOTE:

*To CONVERT I*4 files, select option 4 in "Direct-to-transfer" datatype.*

COUNT - Computes flow accumulation values from flow direction values. COUNT assigns each cell in the COUNT data set a value equal to the number of cells that flow into it. Cells having the flow accumulation value of zero (to which no other cells flow) generally correspond to the pattern of ridges. Because all cells in a depressionless DEM (a product of FILLSNGL and/or CONCAVE) contain a path to the data set edge, the pattern formed by highlighting cells with values higher than some threshold value delineates a fully connected drainage network. As the threshold value decreases, the density of the drainage network increases. COUNT is a part of the conditioning stage for delineating watersheds, however its product also has a value for delineating drainage networks and potential stream flow modeling.

Input parameters:

Number of lines or rows (NL),

Number of samples or columns (NS),

Restart option if processing interrupted (CODE 1 TO RESTART),

Name of flow direction file in single quotes (DIR FILE),

Name of the flow accumulation file in single quotes (COUNT FILE),

Name of the system in single quotes, here it is 'PRIME' (SYSTEM)

```
OK, R COUNT
 ENTER NL,NS,CODE 1 TO RESTART,DIR FILE,COUNT FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,0,'DIRECT.MAP','COUNT.MAP','PRIME'
 DOWNWARD PASS     1
 UPWARD PASS     2
 DOWNWARD PASS     3
 UPWARD PASS     4
 DOWNWARD PASS     5
 UPWARD PASS     6
 DOWNWARD PASS     7
 UPWARD PASS     8
 DOWNWARD PASS     9
 UPWARD PASS    10
 DOWNWARD PASS    11
 UPWARD PASS    12
 DOWNWARD PASS    13
 UPWARD PASS    14
**** STOP
```

DELTA - Computes flow accumulation increments from flow accumulation (COUNT) values. DELTA is a process used in automatic delineation of watersheds where the user provides a threshold flow accumulation value at which watershed pour points should be inserted. DELTA value represents the amount of increase in flow accumulation value in the direction of flow. The program computes DELTA values for every cell by subtracting the flow accumulation value of a cell from the flow accumulation value of a cell into which it flows. Imagine that two cells with a flow accumulation value of 1000 flow into a single cell with a flow accumulation value of 2000. The DELTA value of each of these cells is 1000. Since they both flow into the same cell, they form a junction of potential streams or channels. In the area where there is no juncture of tributaries along the stream channel, the DELTA value or the flow accumulation increment is always 1 because flow proceeds from one cell to another cell. At the juncture of tributaries a sudden increase in flow accumulation values is realized. Therefore, DELTA program identifies locations of flow junctures, and the map created by it is one of the data components used to find locations of watershed pour points using the SEED program for watershed delineation with the WTRSHED program. (See SEED and WTRSHED).

Input parameters:

Number of lines or rows (NL),

Number of samples or columns (NS),

Name of flow direction file in single quotes (DIR FILE),

Name of the flow accumulation file in single quotes (COUNT FILE),

Name of the delta file in single quotes (DELTA FILE),

Name of the system in single quotes, here it is 'PRIME' (SYSTEM)

```
OK, R DELTA
  ENTER NL,NS,DIR FILE,COUNT FILE,DELTA FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'DIRECT.MAP','COUNT.MAP','DELTA.MAP','PRIME'
**** STOP
```

DIRECT - Computes flow direction values from a DEM. The flow direction for a cell is the direction water flows out of the cell, and the flow direction value corresponds to the orientation of one of
the eight cells that surround it as follows:

64(NW)	128(N)	1(NE)
32(W)	center	2(E)
16(SW)	8(S)	4(SE)

There are four possible conditions to consider in determining flow direction. The first condition applies only to single cell depressions, when the immediate surrounding cells have a value higher than the center cell, a condition true only in the unfilled DEMs. In that case DIRECT assigns a negative value to the depression and provides a message stating “COULD NOT SOLVE FOR ALL CELLS”. The second condition occurs when the distance-weighted drop from the center cell is higher for one of the surrounding cells than for the other neighborhood cells. A flow direction value is assigned to the center cell that leads to the cell where the drop (or the slope gradient) is the steepest. Most of the situations are like this. In the third case, there are two or more cells that have the same steepest drop, and one has to be selected as the direction of flow. This is accomplished using a logical table look-up operation, where, for example, if three adjacent cells have the same steepest drop from the center cell, the program selects the middle one of these cells for flow direction. Another possibility for this example is if two cells on opposite sides have an equal drop, then the program arbitrarily choses one of them. In the fourth condition the center cell is located in a flat area and all cells are equal (or greater) in elevation. The outflow point is not known. Consequently, processing requires that all the cells belonging to the first, second, or third condition be resolved, and then, in an iterative process, assigns flow direction to neighboring cells if the neighbor has a defined flow direction that does not point back to the tested cell. In this way the flow direction assignments grow into the flat area from the flats' outflow point until all the cells have flow directions assigned. DIRECT is a part of the conditioning stage for delineating watersheds, however its product also has a value for helping visualize general flow patterns on the landscape. It can be applied to an unfilled DEM or to a filled DEM.

Input parameters:

Number of lines or rows (NL),

Number of samples or columns (NS),

Restart option if processing interrupted (CODE 1 TO RESTART),

Name of the elevation file in single quotes (LEV FILE),

Name of the flow direction file in single quotes (DIR FILE),

Name of the system in single quotes, here it is 'PRIME' (SYSTEM)

```
OK, R DIRECT
 ENTER NL,NS,CODE 1 TO RESTART,LEV FILE,DIR FILE,SYSTEM(U
   NIX,VMS,PRIME)
472,369,0,'DEM.MAP','DIRECT.MAP','PRIME'
  Open ELEV and DIR files, ns =      369
 DEM.MAP
   opened successfully
 DIRECT.MAP
   opened successfully
 DOWNWARD PASS  1FIRSTL 2LASTL  471
 UPWARD PASS    2FIRSTL 7LASTL  465
 DOWNWARD PASS  3FIRSTL 7LASTL  461
 COULD NOT SOLVE FOR ALL CELLS
**** STOP
```

FILLSNGL - Fills single-cell depressions in a DEM. The program looks at each cell in comparison to its adjacent eight cells in a 3x3 window (i.e., a nine-cell neighborhood). If the cell is lower in value than all of its neighbors, the program raises the cell's value to that of its lowest neighbor. While CONCAVE also fills single cell depressions, this program generates a data set which helps in distinguishing between single-cell and multi-cell depressions. FILLSNGL reads from and writes to the original DEM file, so make a copy of the original.

Input parameters:

Number of lines or rows (NL),

Number of samples or columns (NS),

Name of the unprocessed, original elevation file in single quotes (TOPO FILE),

Name of the system in single quotes, here it is 'PRIME' (SYSTEM)

```
OK, R FILLSNGL
 ENTER NL,NS,LEV FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'DEM.MAP','PRIME'
  Open as a Prime direct access file, ns =     369
 DEM.MAP
   opened successfully
**** STOP
```

IMPORT (MAPS) - this MAPS command permits conversion and import of sequential access raster transfer (IDIMS) files into the MAPS system. The Moss User's Manual describes the IMPORT command in detail. What follows is a brief description of new IMPORT capabilities which permit import of I*4 maps into MAPS. Install the new IMPORT version included with the HTAS package in a directory of your choice and set up PTHBLK.DT in the directory from which you are running MOSS/MAPS so that when IMPORT is used the new version is found. The new version is provided in files IDIMS.RUN and IDIMPR.RUN.

Below is an example of how the MAPS IMPORT command works with the I*4 maps. The import I*4 maps use the "DOUBLEWORD" instead of the "WORD" option.

```
 OK, R IDIMS
  SINGLE COMMAND VERSION OF MAPS
  ONLY BYE AND IMPORT WILL WORK

    0 MAPS IN     WORK PROJECT POLYGON
       NO MASTER PROJECT IS OPEN
?
IMPORT COUNT.MAP.16 FORMAT IDIMS DOUBLEWORD FOR COUNT.MAP
  TYPE 8
 ENTER THE FOLLOWING INFORMATION FOR INPUT MAP
 NUMBER OF ROWS ?
472
 NUMBER OF COLUMNS ?
369
 CELL HEIGHT (IN METERS) ?
30
 CELL WIDTH (IN METERS) ?
30
 ENTER THE MINIMUM BOUNDING RECTANGLE
 MINIMUM X (WEST) ?
702750
 MAXIMUM X (EAST) ?
713820
 MINIMUM Y (SOUTH) ?
4416390
 MAXIMUM Y (NORTH) ?
4430550
 ENTER MAP PROJECTION INFORMATION
 PROJECTION(0-20) ?
1
 ELLIPSOID(0-19) ?
0
 LONGITUDE OF ANY POINT WITHIN THE UTM ZONE ?
```

```
-109
 LATITUDE OF ANY POINT WITHIN UTM ZONE   12 ?
35
 ENTER MAP DESCRIPTION INFORMATION
 MAP DESCRIPTION ?
WATERSHEDS BASED ON THRESHOLD OF 3000
 STUDY AREA ?
WOLSAG
 PROJECTION DESCRIPTION ?
UTM
 DATE ?
10/01/92
 SOURCE ?
```

MAPSTOIDIMS - Permits conversion of raster files in MAPS format into the sequential access raster transfer format (IDIMS) as an operating system (PRIMOS) level utility. Originally written to convert and write files to tape, this command also converts and writes files to disk by using defaults. MAPSTOIDIMS creates files with .16 and .TH suffixes after the name of the input file. The .16 files are the raster files used for processing, while the .TH files contain information about various parameters of the file, such as number of rows and columns or coordinates of the Minimum Bounding Rectangle (the window of the map) to which the user may refer.

```
OK, MAPSTOIDIMS
              MAPS TO IDIMS CONVERSION
 Enter macro file name to execute file copy
  ( Default is TMCOPY )
<CR>
 Enter tape drive name MT0 or MT1 ( Default = MT0 )
<CR>
 Enter tape drive density (800, 1600 or 6250; Default = 1600 ) :
 How many maps are already on this tape ?
:<CR>
 Please enter the DIRECTORY (under MOSSDATA) or WORK
 and the .DT (project master or POLYGON :
 i.e., WOLSAG WOLSAG.DT  or  WORK POLYGON.DT
: WOLSAG 32 WOLSAG32.DT
Enter map name ( CR = End )
: DEMFILE
 Map- DEMFILE  has been processed.
Enter map name ( CR = End )
:<CR>
  * INSTRUCTIONS TO COMPLETE MAPSTOIDIMS *
  1) List out the .TH file created in the
     same directory that the MAPSTOIDIMS was
     executed (SPOOL or SLIST on the PRIME).
     This file contains the MBR, cell size,
     and projection criteria of the file,
     and needs to accompany the TAPE
     transfered to IDIMS
  2) R the macro called TMCOPY to transfer
     the cell file to magnetic tape:
     •         Mount the tape
     •         R TMCOPY (CPL TMCOPY)
  MAPSTOIDIMS completed.
**** STOP
```

WARNING:

MAPSTOIDIMS works only with 16-bit (word length) integer data and some of the MAPS real number files 32 (double word) data. To correct this problem use the FUNCTION command INTEGER option in maps which will convert the real number 32-bit map into an integer 16-bit map.

MINIM - Finds local minima and flats in a DEM. The MINIM program reads an elevation file and examines each cells neighborhood within a 3x3 window (a nine cell neighborhood). If any of the endpoints of symmetric cross-sections through the neighborhood are higher than the center, then the program gives the center cell a value of 2 to represent the bottom of a valley, or a V-shape on the landscape. If the cell is equal in value to all its neighbors, it is a flat and receives a value of 3. MINIM-delineated cells, which identify valley-shaped areas and flats, form a crude unconnected drainage network. Use OVERLAND to connect these cells and follow the flow path between them to delineate a drainage pattern.

Input parameters:

Number of lines or rows (NL),

Number of samples or columns (NS),

Name of the unprocessed, original elevation file in single quotes (TOPO FILE),

Name of the new minima file in single quotes (MINIMA FILE)

Name of the system in single quotes, here it is 'PRIME' (SYSTEM)

```
OK, R MINIM
 ENTER NL,NS,TOPO FILE,MINIMA FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'DEM.MAP','MINIMA.MAP','PRIME'
 COMPLETED A MOREFLATS PASS
**** STOP
```

OVERLAND - Traces overland paths for user-specified cell(s) contained in a starter data set. The program uses the flow direction data set to produce a path or paths by following the cell-to-cell linkage (how cells flow into each other) starting from the user specified cell(s) until it reaches the data set edge. Create the starter data set by generating the points in MOSS to represent point sources, rasterizing them to MAPS format, converting them using MAPSTOIDIMS and CONVERT to the direct access file format used by the HTAS. The OVERLAND process assigns the starter, or point source cell label to all the cells it flows into, i.e., to the entire path. The results of this process are helpful in tracking the overland path from point sources of pollution into nearby streams. When using OVERLAND on a data set created by MINIMA, it delineates a complete drainage network pattern for the modeled area.

Input parameters:

Number of lines or rows (NL),

Number of samples or columns (NS),

Name of the flow direction file in single quotes (DIR FILE),

File containing points for which the path is modeled (MASK FILE),

Name of the system in single quotes, here it is 'PRIME' (SYSTEM)

```
OK, R OVERLAND
 ENTER NL,NS,DIR FILE,MASK FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'DIRECT.MAP','SOURCES.MAP','PRIME'
 PASS       1
 PASS       2
 PASS       3
 PASS       4
**** STOP
```

PPTABLE - Builds a table of pour points for watersheds. To accomodate data sets where there are internal or closed drainages and where pour points are very close or equal in elevation for watershed A to drain to either watershed B or C, this program computes all possible pour points. For each watershed, the program examines every bordering watershed (including the zero or off the edge watersheds). The table includes information on the label, elevation and location of the pour point on the map in line (row) and sample (column) format.

Input parameters:

Number of lines or rows (NL),

Number of samples or columns (NS),

File of watersheds delineated using WTRSHED in single quotes (BASIN FILE)

Name of the elevation file in single quotes (LEV FILE),

Name of the table to be produced in single quotes (TABLE NAME)

Name of the system in single quotes, here it is 'PRIME' (SYSTEM)

```
OK, R PPTABLE
 ENTER NL,NS,BASIN FILE,ELEV FILE,TABLE
  FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'SEED.MAP','DEM.MAP','PPTABLE.SEED','PRIME'
**** STOP
```

NOTE:

The DEM.MAP can be the original DEM, the FILLSNGL processed DEM, or the CONCAVE processed DEM.

```
OK, SLIST PPTABLE.SEED
1       THIS IS THE COMPLETE LIST OF POUR POINTS
  SEQUENCE NO. LABEL   PAIR    ELEVATION        LINE    SAMP
   1           0/       1      2070             2        0
   2           0/       2      2151             4        0
   3           0/       3      2146             7        0
   4           0/       4      2126             7        0
   .
   .
   .
   163         55/     56      2608             448     49
   164         0/      50      2485             453      0
   165         0/      56      2381             469      0
   166         0/      54      2194             463      0
```

RSNAP - Finds a cell with the nearest flow accumulation value above a user specified flow accumulation threshold and within a threshold distance from a manually generated seed cell. The user specifies a threshold distance as a value for the number of cells in the line (row) and sample (column) direction that represent the neighborhood around the seed cell. The program then snaps a manually delineated seed cell to the location of the cell it found.

When manually defining watershed pour points a problem might arise in that the newly created seeds are not registered to the modeled drainage patterns. For example, a pour point generated only on the basis of DLG stream data might fall slightly outside of the drainage pattern derived using the HTAS. In such a case the flow accumulation value of the pour point is low because it is considered to lie outside of the drainage network. Since few cells are modeled as flowing into it, the program delineates only a very small watershed for this pour point. RSNAP snaps the user defined pour points to a cell on the HTAS modeled drainage pattern so that they are properly registered to the DEM, allowing full delineation of watersheds. RSNAP reads from and writes to the same file, therefore make a copy of the original file in the HTAS format. RSNAP can process only up to 999 points.

Input parameters:

Number of lines or rows (NL),

Number of samples or columns (NS),

The lowest flow accumulation to which the seed can be snapped (FLOW THRESHOLD)

The distance threshold from the original seed (DISTANCE THRESHOLD)

Name of the user defined pour point or seed file in single quotes: (SEED FILE),

Name of the flow accumulation file in single quotes (COUNT FILE),

Name of the system in single quotes, here it is 'PRIME' (SYSTEM)

```
OK, R RSNAP
  ENTER NL,NS,FLOW THRESHHOLD,DISTANCE THRESHHOLD,SEED FILE,COUNT
  FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,100,50,'MANUALSEED.MAP','COUNT.MAP','PRIME'
   MOVED SEED FOR  85 FROM  30,     251 TO    29,     250(1.41421
   CELLS)
   MOVED SEED FOR  65 FROM  66,     207 TO    67,     207(1.00000
   CELLS)
   MOVED SEED FOR  66 FROM  69,     206 TO    69,     205(1.00000
   CELLS)
   MOVED SEED FOR  88 FROM  82,      94 TO    83,      94(1.00000
   CELLS)
   MOVED SEED FOR  67 FROM  83,     187 TO    83,     188(1.00000
   CELLS)
   .
   .
   .
   MOVED SEED FOR 109 FROM 358,     146 TO   359,     146(1.00000
   CELLS)
   MOVED SEED FOR 106 FROM 362,     102 TO   363,     102(1.00000
   CELLS)
   MOVED SEED FOR 111 FROM 421,     144 TO   421,     145(1.00000
   CELLS)
   TOTAL OF      22 POINTS MOVED
       114 SEED CELLS WERE FOUND
**** STOP
```

SEED - Finds starting or "seed" points for automatic watershed generation at the outlets of potential stream tributaries on the drainage pattern modeled using the HTAS. SEED accepts user input of the values (in number of cells) for the flow accumulation threshold above which the pour points of watersheds can be found. It also uses flow accumulation (COUNT) values and DELTA values. For each cell where both the flow accumulation value and the delta value are greater than the flow accumulation threshold, it assigns to this cell a unique positive value. This means that for a given threshold the program places a seed where the DELTA value or a flow accumulation increment between two cells is above that threshold and where the flow accumulation (COUNT) value is above that threshold. The first condition effectively places the "seed" where there is a juncture or tributary relationship between two potential streams, and the amount of flow input (the increment) is above the threshold. The second condition eliminates any streams which have a flow accumulation value below the threshold as being too insignificant to have "seeds" created, thereby eliminating minor tributaries. The cells that fit these criteria represent a pour point or a "seed" of an automatically delineated watershed and receive a positive value. The watersheds developed from each of these pour points receives the value of the "seed" when using the WTRSHED program. The background cells in the SEED data set receive a value of -1.

Input parameters:

Number of lines or rows (NL),

Number of samples or columns (NS),

The flow accumulation threshold for pour points (THRESHOLD),

Do you want seeds at edges of the data set: 1 = no; 0 = yes (EDGES),

Name of the seed file in single quotes: (SEED FILE),

Name of the delta file in single quotes (DELTA FILE),

Name of the flow accumulation file in single quotes (COUNT FILE),

Name of the system in single quotes, here it is 'PRIME' (SYSTEM)

```
OK, R SEED
  ENTER NL,NS,THRESHHOLD,EDGES,SEED FILE,DELTA FILE, COUNT
  FILE,SYSTEM(UNIX,VMS,PRIME)
  472,369,3000,1,'SEED.MAP','DELTA.MAP','COUNT.MAP','PRIME'
  20 BASINS WERE SEEDED
**** STOP
```

WTRSHED - Finds watersheds for "seed" cells that represent user specified or automatically assigned pour locations. Delineation of watersheds requires both a flow direction data set and another "starter" or "seed" data set which represents watershed pour locations. The starter data set consists of background values of -1 in which a "seed" cell or groups of cells were inserted at the outflow points of the desired watersheds, with each start cell or group of cells having its own unique positive value. The "seed" starter data set is created automatically using SEED or manually by generating the points in MOSS, rasterizing them to MAPS format, converting them using MAPSTOIDIMS and CONVERT to the direct access file format used by the HTAS, and snapping them to the HTAS modeled drainage pattern using RSNAP. Using the flow direction data set, WTRSHED than iteratively reassigns the background values of cells in the starter data set to the value of the "seed" cell or group of cells into which the background cells flow. The program reads and writes to the SEED file, so make a copy of the original.

Input parameters:

Number of lines or rows (NL),

Number of samples or columns (NS),

Name of the flow direction file in single quotes (DIR FILE),

The name of the seed file in single quotes (MASK FILE),

Name of the system in single quotes, here it is 'PRIME' (SYSTEM)

```
OK, R WTRSHED
 ENTER NL,NS,DIR FILE,MASK FILE,SYSTEM(UNIX,VMS,PRIME)
472,369,'SGHL.DIR','SGHL.SHED','PRIME'
 PASS        1
 PASS        2
 PASS        3
 PASS        4
 PASS        5
 PASS        6
 PASS        7
 PASS        8
 PASS        9
 PASS       10
 PASS       11
 PASS       12
 PASS       13
 PASS       14
**** STOP
```

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Resource & Environmental Modeling Applications with the HTAS

There are numerous potential resource and environmental applications of the HTA software (HTAS). The following descriptions of applications are very general and only suggest possible uses.

Soil erosion prediction

Users can model sheet and rill soil erosion with GIS using the current MOSS/MAPS capabilities interfaced with the Revised Universal Soil Loss Equation (RUSLE). However, the CONCAVE program in HTAS provides an added capability to identify potential sediment sinks in the landscape, thus identifying areas of potential deposition. The software is also being tested as an alternative method for determining slope lengths. Currently, documentation is being prepared that describes the GIS methodology for sheet and rill soil erosion modeling with the RUSLE.

Runoff modeling using the SCS Curve Number method

The SCS Curve Number method generates storm hydrographs for watersheds. It interfaces with GIS to help determine runoff. The smaller the watershed, the more precise this information is likely to be. HTAS permits subdivision of watersheds into small subwatersheds, and thus provides a smaller analytic unit for this type of calculation. Currently documentation is being prepared that describes the GIS methodology for runoff modeling.

Sediment yield modeling

Runoff information generated using the SCS Curve Number method can be used to provide the R (runoff) factor for the Modified Universal Soil Loss (MUSLE) equation to calculate sediment yield from each subwatershed. Currently documentation is being prepared that describes the GIS methodology for sediment yield modeling using MUSLE.

Dam and reservoir design

Using both the MOSS/MAPS and HTAS capabilities it is possible to delineate watersheds for dams, and thus obtain information useful in determining dam placement. By inserting information on the elevation of potential dams into a DEM, and therefore creating a depression in the landscape which is then filled using CONCAVE, one can model the area and volume of reservoirs created by the dam at any level of water up to the elevation of the spillway. The resultant map may illustrate the areal extent and volumes at various water levels. Currently documentation is being prepared that describes this GIS methodology.

Determining the location of surface structures to control erosion

Flow information provided by the HTAS can be used to determine the optimum locations for placement of erosion control structures, such as spreaders and pits. This methodology has not yet been developed.

Drainage pattern delineation/ gully and channel development

The flow accumulation map permits modeling of drainage patterns on the landscape, which is particularly useful in the absence of other data. It will also probably help in identifying likely areas of gully and channel development, depending on the resolution of the digital elevation data. This methodology has not yet been developed.

Stream flow modeling

Being able to obtain values for accumulation of flow along the landscape, when used in conjunction with rainfall, runoff, channel slope and other data, should permit stream flow modeling and stream sediment carrying capacity using combined GIS and HTAS capabilities. This methodology has not yet been developed.

Locating aquifer recharge area

It is known that aquifer recharge areas are generally located in topographic depressions. HTAS provides that information. When used with information on soil infiltration and presence or absence of an upper confining layer, it should be possible to model aquifer recharge areas using GIS. This methodology has not yet been developed.

Riparian area modeling

Besides permitting determination of influx and routing of sediment in streams, the HTAS permits determination of areas where water might pond, loosing its energy and thus deposit the sediment. This methodology has not yet been developed.

Many other applications are possible and are being explored. If you have any suggestions or experiences in the other applications, or are interested in finding out more about the one described above, please contact:

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Let us know.

This manual is the result of our effort to improve both the content and appearance of Service Center documentation. We have made every effort to ensure that this manual is as functional as possible, but we would like you to point out any errors that you discover. This version of the HTAS User's Guide contains many changes and improvements that were inspired by comments from the user community.

1. Did you have any difficulty understanding or using this manual?

☐ No Difficulty ☐ Some Problems ☐ Great Difficulty

If you had difficulty, what specific areas caused you problems?

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This report introduces, and provides instructions on using, the Hydrologic Terrain Analysis Software (HTAS) developed by S. Jenson from the Eros Data Center. HTAS provides a series of tools to delineate watershed and subwatershed boundaries from digital elevation data. It consists of several FORTRAN programs that can be run under PRIMOS, UNIX, or VMS operating systems. Data can be transferred between the HTAS and MOSS/MAPS GIS. The programs permit automatic delineation of watersheds at a regular flow accumulation interval, as well as delineation of watersheds for user specified pour points, linear features (e.g., dams), and polygonal features (e.g., lakes and reservoirs). The programs also permit filling of large depressions in digital elevation models (DEMs) to identify depositional basins, detection of drainage patterns to predict flow along a landscape, and determination of overland flow path from point sources such as a spring or a source of pollution. The author also suggests various possible resource and environmental modeling applications of the HTAS, some of which have already been developed.

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